Day 1: Sessions 1 & 2

An Appraisal of 2005/2006 ENSO Evolution and Forecasts

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Historically since 1950, ENSO episodes have tended to occur with approximately one-year duration, beginning near April-to-June of one year and ending near March-to-May of the following year. Notable exceptions exist, such as multi-year episodes (e.g. 1954-57, 1986-88, 1998-2000) and part-year episodes (e.g. early to mid-1993). Despite these exceptions, a rule that has held up has been that the ENSO condition observed during the northern autumn has had a strong tendency to persist into the coming northern winter. In fact, the autocorrelation of the NINO3.4 SST anomaly in Sep-Oct-Nov (SON) with that in Dec-Jan-Feb (DJF) in the Nino3.4 region for the 1950-2005 period was 0.94. Accordingly, until 2005, there was never a decrease from a near-zero NINO3.4 SST anomaly in SON to an anomaly in DJF sufficient to be considered a La Niña, such as -0.5 or stronger. However, this happened in 2005-06, when a NINO3.4 SST anomaly of -0.03 in SON strengthened to -0.68 in DJF. The only other occasion when the SST anomaly decreased this much was in 1987-88, when the 2-year El Niño rapidly weakened (from 1.55 to 0.83) from SON to DJF—but this did not involve a new ENSO development. What caused the rare cold event development in late 2005 at a time of year when the ENSO state is normally stable?

The answer may be related to initially localized events in the far eastern tropical Pacific. During early September 2005, negative anomalies began to develop off the west coast of South America and extended to approximately 110W. The cause of that localized anomaly appears to have been a region of enhanced high pressure over western South America and the southeast tropical Pacific, just south of the equator. This high pressure anomaly led to enhanced southeast trades and cross-equatorial flow, and to an increase in coastal and equatorial upwelling in the region. This pressure anomaly was strongest in September, and weakened considerably by mid-November. However, easterly wind anomalies developed along the equator in middle to late November in response to the anomalous east-to-west temperature gradient. The enhanced easterlies both advected the cold anomalies westward and decreased the depth of the local thermocline, increasing the magnitude and spatial extent of the negative anomalies in the eastern equatorial Pacific from mid-November to mid-December 2005. In December the spatial extent became sufficient to impact the NINO3 and then even the NINO3.4 SST anomalies, leading to a more basin-wide coupling with the atmosphere. La Niña SST conditions became established by early December, and continued for three to four months.

Because of the rarity of ENSO development near the end of a calendar year, none of the ENSO prediction centers had forecast La Niña onset prior to its actual appearance. In early December, as the below normal SST in the far eastern tropical Pacific expanded westward, the NOAA Climate Prediction Center (CPC) was the first to formally recognize it. The International Research Institute for Climate and Society (IRI) was approximately one month slower in acknowledging it, and the Australian Bureau of Meteorology (BoM) never recognized it as a La Niña event but rather as a neutral ENSO pattern with some cold event characteristics. NOAA’s promptness in acknowledging the La Niña condition may be due in part to the fact that their CFS model had been predicting the onset of such a statistically unlikely ENSO development for several months. The CFS forecast was one of the coldest among the many model forecasts shown on the IRI’s plume of ENSO forecasts developed each month.

La Niña SST conditions endured from early December through mid-March, and although this is not long enough to meet NOAA’s requirements for an ENSO episode, climate responses were evident in some regions. During the northern winter season of December to February, there were positive anomalies in most of Indonesia, southeast Asia, the Philippines, part of southern Africa, and northwestern U.S.; and negative anomalies in the central and eastern tropical Pacific, and southern U.S. Atypical anomalies included below normal rainfall in eastern and northeastern Australia, and above normal rainfall along the coast of Peru and Ecuador. Some exceptions are expected even for stronger, longer-lived, more canonical ENSO episodes. The observed responses during this brief cold episode support the notion that ENSO conditions need not endure for multiple seasons in order to have visible impacts on the climate; i.e. that 2-4 months may be sufficient to tilt the odds of the climate in a majority of the expected regions in the expected manner.

2005/2006 U.S. Drought Conditions, Drought Outlooks, and Verifications

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There were a number of notable droughts during 2005-06 that led to major impacts on fire danger, crop production, and water supplies, including the Southwestern drought, which resulted from near-record low winter precipitation; continuation of the southern Plains drought; development across the northern Plains in the summer of 2006; continuation of drought across much of the central Plains into summer 2006; and continuation of drought along the Gulf of Mexico coast, expanding into interior sections of the Gulf states during July 2006. Excessive heat during the 2006 summer exacerbated drought conditions in many areas, and by early August the U.S. Drought Monitor showed about one-half of the CONUS in drought. The U.S. Seasonal Drought Outlook had some hits and some misses, flagging development of drought in the southern Plains in an early December 2005 update and expansion of drought in the Southwest in the mid-December release. The summer expansion of the drought into the northern Plains was not forecast until the July 7 update, and none of the Outlooks flagged the northward expansion of the Gulf coast drought. Nevertheless, the Outlooks continued to consistently beat forecasts based on persistence. Examining verification statistics reveals some interesting patterns in skill versus time-of-the-year. Some of the statistical and numerical models that have been relatively helpful in forecasting drought are shown, and future prospects for improving monitoring and forecasting are discussed, including some ideas on the role that drought forecasts may play in the National Integrated Drought Information System (NIDIS).

Day 1 & 2: Climate Testbed
(Sessions 3-5)

Developing Improved Climate Products for Effective Climate Risk Management

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Over the past two decades climate scientists have made significant gains in understanding and prediction of seasonal temperature and precipitation anomalies. The ability to understand and predict, in a probabilistic way, seasonal rainfall and temperature anomalies is a great achievement. However, the adoption of this prediction capability by many user communities has not yet occured. This is, in part, the result of the mismatch between the products and services that the climate community are providing and what the user community perceives that it needs.

While the climate community has long recognized that it needs to involve users in the development of climate products, the nature of the involvement with users is not generally clear. This talk will discuss some of the factors that should be considered in interactions with users for the development of improved climate products that can be used in effective climate risk management. Among the necessary considerations are: 1) Awareness of factors <u>other</u> then climate effecting the system, 2) Understanding of the factors (Internal and External) which limit the users ability to interpret and act on information 3) Awareness that there may be alternatives to those offered in the use of climate information and 4) Understanding the flexibility in decision making and how much flexibility resides in the system. These factors will be briefly discussed in a series of examples developed in work on regional projects.

Firedanger Applications of NCEP's Downscaled CFS Forecasts

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The Scripps Experimental Climate Prediction Center (ECPC) has been making experimental, near real-time, weekly to seasonal US fire danger forecasts for the past 9 years with the Regional Spectral Model (RSM). These fire danger forecasts are based on standard indices from the National Fire Danger Rating System (NFDRS), which include the: Ignition Component (IC), Energy Release component (ER), Burning Index (BI), Spread Component (SC), and the Keetch Byram drought index (KB). The Fosberg Fire Weather Index (FWI), which is a simplified form of the BI, has been previously used not only for the US but also for other global regions and has also been included for comparison. As shown by Roads et al. (2005: Seasonal fire danger forecasts for the USA. International J. Wildland Fire, 14, 1-18), all of these indices can be predicted well at weekly times scales and there is also significant skill out to seasonal time scales over many US West locations. The most persistent indices (BI, ER, and KB) tend to have the greatest seasonal forecast skill although, FWI, ER and BI tend to be best related to observed fire characteristics such as fire counts (CN) and acres burned (AC) over the US West. We are attempting to transfer this experimental fire danger forecasting methodology to the US National Centers for Environmental Prediction (NCEP) by now using the recently developed NCEP global and regional seasonal forecast ensemble forecasts initialized with the Climate Forecast System (CFS). In particular, an ensemble (3 prior to Oct. 2004, 10 thereafter) of 7-month global and regional fire danger forecasts, initialized from continuous simulations of the fire danger indices, forced in part by 1-day RSM forecasts and in part by observed precipitation, are now being made for every month beginning 1982 to present. Preliminary evaluations indicate that these new multi-seasonal fire danger forecasts have significant forecast skill at weekly to seasonal time scales and thus may be useful for the USFS and other fire communities, which need long-horizon and high-resolution fire danger forecasts for resource allocation and community preparedness.

Objective Verification of CPC Forecasts

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A system has been devised to objectively verify Climate Prediction Center seasonal and monthly temperature and precipitation forecasts on a 2° x 2° grid. The system uses a vast array of station observations (about 5000 for precipitation, 3000 for temperature) to provide more complete coverage over the continental U.S. The final verification uses 232 equally spaced grid squares across the country, which compares to the roughly 100 first order stations used in the older verification system. The verification data set also makes it routine to verify many of the tools that are used in producing the forecasts. In particluar, the CPC seasonal forecast consolidation tools has been verified for the period 1995-2006 and has shown to score about 10% higher than the official CPC forecasts for non-EC areas. This gridded verification set will be extended to verify the 6-10/8-14 day forecasts as well.

Assessing the Value of Seasonal El Nino Forecasts for the Panama Canal

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The Panama Canal relies on rain-fed streamflow into Gatun and Madden Lakes for operations – principally ship transits, hydroelectric generation and public water supply. Precipitation in the Canal watersheds, as in much of Central America, is strongly modulated by El Nino variability, with strong warm events being associated with reduced rainfall and river discharge. Further, research over the past two decades has led to the development of operational seasonal forecast systems with demonstrated skill for forecasting tropical Pacific sea surface temperatures (SSTs). These SST forecasts can be translated into probabilistic inflow predictions for the Canal system. Our research considers the value of such guidance information for canal operations and planning. To do so we use a three element system composed of the following:

i) a canal simulation system,

ii) an optimization scheme for assessing the efficacy of operations policies given a particular distributions of forecast inflows, initial conditions, constraints, penalties and rewards, and

iii) a system for assessing the value accrued by implementing forecast-derived operations policies.

The results emphasize three main points. First, under current demand and supply levels, the Canal system is robust (forecasts are of little value) except during El Nino years or if the forecasts are extremely accurate. Second, relatively small increases in demand make the Canal system much more sensitive to inflow variability, and forecast information increases in value. Third, the value of the forecast information is quite sensitive to correct specification of the associated probability distributions; incorrect specification of outcome probabilities (i.e., a lack of statistical reliability) can rapidly degrade value, even if the forecast expectation is correct.

With respect to applications of climate forecast information in a general sense, these findings emphasize the importance of rigorous understanding how a particular system (or groups of systems) will respond to forecast information of varying degrees of quality. Through such understanding the value of forecast information can be maximized (if any can be attained) and the risk of causing damage can be reduced.

Development of a Tool for Downscaling of Operational Climate Forecasts to Regional and Local Fire Indices

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To plan ahead of a forest fire season, fire management agencies request information on the potential severity of a fire season several weeks ahead of the season. Their decision making processes are mainly based on experience and rely on available operational climate prediction data. For obtaining the predictions in realistic time and computational reasons, the resolution of operationally used climate models is relatively coarse. Consequently, such climate models do not resolve many aspects relevant for predicting fire weather indices.

A method is presented that permits to improve the prediction of forest fire seasons. The tool translates data provided by operational climate predictions into likelihood for severe convection and fire risk to better assess the coming fire season. Herein the Weather Research and Forecasting (WRF) model serves to derive fire indices and to build statistics on how often severe convection is predicted under which synoptic situations (requirement for ignition). The classification of synoptic situations and the related fire indices permits interpreting the climate prediction data in terms of probability for severe convection and determining fire indices on the regional/local scale. The method is illustrated for the 2005 wildfire season in Interior Alaska, the third severest fire season since recording started in 1940.

The Global Ocean Data Assimilation System (GODAS) at NCEP

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The Global Ocean Data Assimilation System (GODAS) is a 3D variational assimilation system that has as its primary purpose to provide ocean initial conditions for seasonal to interannual (S/I) forecasting with the NCEP Coupled Forecast System (CFS). This presentation will provide a general description of the current operational version of GODAS and of recent developments that will become part of future versions. There will be particular emphasis on the importance of constraining salinity as part of the assimilation, on the impact of assimilating altimetry data and on some technical improvements that have been developed under the aegis of the NOAA Climate Test Bed. Because S/I prediction has focused on the ENSO phenomenon, ocean observations in the tropical upper ocean have been most important to GODAS. Also, because S/I forecasts must be calibrated by a long series of hindcasts, a data set that spans 20+ years is required. Given these criteria, GODAS relies heavily on ocean profiles of temperature (XBT, TAO/TRITON, Argo) and on sea surface temperature (SST). The stability of the TAO/TRITON mooring array since its establishment in the early 1990s and the recent growth of the Argo autonomous drifter array mean that *in situ* profiles will retain their central importance. However, if only temperature observations are assimilated, the result is a significant degradation of the tropical salinity field. Historically, ocean observations of salinity have been too sparse to be of practical use, but constraining GODAS salinity by the climatological relationship between temperature and salinity has proven to be a workable solution. In the future a better solution will be provided by the Argo array which produces, in addition to temperature profiles, the first extensive global set of salinity profiles. Initial experiments show that when the GODAS is adapted to use Argo salinity profiles, there is a measurable improvement in the GODAS salinity field and some improvement in tropical surface currents. The Argo array has only approached full global coverage during the last 2 years and several more years will be needed to fully gauge the impact of these data. A consistent, uninterrupted altimetry data set has been available since late 1992 from the TOPEX and Jason-1 (T/J-1) satellites. Experiments demonstrate that, in the equatorial Pacific, the assimilation of the TAO/TRITON mooring data already leads to a good representation of tropical SSH in the operational GODAS. In the Pacific, the additional assimilation of T/J-1has slight impact in the tropics but improves GODAS SSH beyond the bounds of the TAO array and well into the subtropics. In the Atlantic and Indian Oceans, where there are no exact equivalents of the TAO/TRITON array, the assimilation of T/J1 greatly improves the GODAS SSH. The presentation will finish with a description of experiments done within the NOAA Climate Test Bed to examine the impact of deep data assimilation (down to 2500m) and of a multivariate constraint on geostrophic velocity. An important conclusion to be drawn from the presentation is that careful attention to the use of available assimilation data sets and to technical details of the assimilation system can lead to significant improvements in the GODAS representation of the ocean state.

Assessing the NCEP CFS Model Bias

Associated with the Marine Stratus Clouds over Southeastern Pacific

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A preliminary investigation has been conducted to examine the bias in the NCEP operational CFS climate forecast model associated with the insufficiently simulated stratus clouds over SE Pacific. Global fields of SST, surface winds, solar radiation, cloudiness, and precipitation generated by fully-coupled and radiation-corrected CFS simulations have been compared with in situ and satellite observations. Our initial results showed the following:

1) While large-scale precipitation patterns are reproduced reasonably by the CFS CMIP simulations, differences exist in the magnitude of precipitation and in the latitudinal position of the ITCZ over the eastern Pacific sector;

2) The latitudinal displacement of the ITCZ in the CFS CMIP run is closely related to the warm SST bias in SE Pacific stratus deck region;

3) About half of the warm SST bias is attributable to the insufficient amount of stratus clouds simulated by the CFS model (and most other climate models as well);

4) The interannual variability in SST over the central weakens with the reduction in the warm SST bias in the eastern Pacific, and

5) The stratus clouds over the regions have very low cloud tops and exhibit a strong diurnal cycle generated by a regional circulation caused by the contrasting surface conditions between the oceanic regions and their adjacent continents.

Further work is underway to examine the relative importance of the convection over the land areas in forming the stratus clouds and the oceanic processes in forming the warm SST bias. Results will be reported at the workshop.

NCEP's Climate Forecast System Models: T62 vs. T126: Mean State, Seasonal Cycle, ENSO Characteristics and the Impacts of Atmospheric Stochastic Forcings on ENSO

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The NOAA/NCEP operational Climate Forecast System (CFS) is the first Coupled General Circulation Model (CGCM) with ENSO hindcast skill equaling or exceeding that of statistical and intermediate models. The CFS is implemented operationally at NCEP in 2004. Saha et al. (2006) gave a detailed documentation of the hindcast runs of the CFS for the past 22 years and their validation against observations. Four sets of 34 year free simulations are made with the operational CFS. To investigate the impacts of atmospheric noise forcings on simulated ENSO, the operational CFS is modified with its atmospheric model resolution increased from T62L64 to T126L64. Two sets of 100 year simulations are made with the CFS T126L64. In contrast to the CFS T62L64 that simulates too regular ENSO, the CFS T126L64 simulates pronounced decadal variability and decadal modulation of ENSO. Preliminary analysis suggests that the modulation of ENSO oscillates on a period about 20-25 years. To understand the changes of ENSO behavior simulated by the CFS T62L64 and T126L64 models, we conduct detailed analysis of the mean state, seasonal cycle, ENSO characteristics and the impacts of atmospheric stochastic forcings on ENSO in the two models.

Previous theoretical and modeling works suggest that ENSO characteristics are sensitive to the mean state and seasonal cycle of the tropical climate system. However, systematic biases are common in CGCMs, which are mostly derived from the mean states of surface variables, and not much have been done on the seasonal cycles of subsurface thermal and circulation fields. The NCEP's Global Ocean Data Assimilation System (GODAS) and other observation data sets are used to document the model biases with a focus on the seasonal cycles of subsurface thermal and circulation fields.

ENSO characteristics will be accessed in term of SST mode (S-mode) or thermocline mode (T-mode) using the analysis method suggested by Trenberth and Stepaniak (2001) to calculate lag-correlations between the Trans Nino Index (TNI) and Nino3 SST anomalies. Since ocean-atmosphere interactions involve a feedback loop among the thermocline, SST and surface winds, we will calculate the regression coefficients between those variables and NINO indices using a 11-year running window to illustrate how the relationships change with time.

We will also explore to what extent atmospheric and/or coupled stochastic forcings contribute to ENSO irregularity. This mechanism will be investigated using the daily fields from the 100 year CFS T126L64 run. Previous study suggests that atmospheric stochastic forcings associated with the Madden-Julian Oscillation contribute to irregularities of ENSO through generating oceanic Kelvin waves (Seo and Xue 2006). So study of the features of atmospheric stochastic forcings and associated oceanic Kelvin waves will likely contribute to our understanding of the ENSO differences simulated by the two models.

Recent Developments with the new CFS

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The CFS operational implementation in 2004 will be followed by a new implementation in the 2008-2010 timeframe. There are several candidate changes being considered for this implementation. For the atmospheric component of the CFS (the GFS), these changes are closely coordinated with changes that have already been made (or will be made in the near future) in the GFS for medium range weather prediction. In this presentation we will discuss an array of experiments, mostly multi-year long CMIP runs, with elements of change relative to CFS04. These experiments include changes in horizontal resolution (T62 to T126), changes in land surface model (OSU to Noah), etc. Another change may concern the vertical coordinate; both sigma-p and sigma-theta vertical coordinates are being considered. Because of the growing importance of inter-decadal change, we have made some CMIP runs with changing CO2 and solar radiation; this is a new experience at NCEP. Our talk provides an overview of the experiments that are going on. We will also present a general time schedule of all the steps that need to be taken before a new CFS will be a reality; this includes a coupled CFS Reanalysis from 1979-present, and retrospective (hindcast) runs from 1981-present. We close the presentation by summarizing each of the posters on the CFS development to be presented at the Workshop.

Climate Services: The Pacific Climate Information System (PaCIS) Approach

Eileen Shea (Pacific RISA Program and NOAA IDEA Center)

The author will provide an overview of the development and early implementation of a Pacific Climate Information System (PaCIS). PaCIS represents an integrated program of climate observations, data management, research, modeling, forecasting, operational services, assessment and education/outreach. In addition to serving the needs of American Flag and U.S. Affiliated Pacific Islands, PaCIS will all provide the programmatic framework for ensuring an effective U.S. contribution to a WMO Regional Association V Regional Climate Centre.

The author will briefly highlight some of the important lessons learned from fifteen years of experience in the development and application of ENSO-based climate forecasts and climate change assessment efforts in the Pacific Region. The author will review how the lessons learned from are being incorporated into planning for PaCIS. The author will review the evolution of planning for PaCIS and provide the vision, mission objectives and program elements of PaCIS. In this context, the author will review how programs such as the Pacific ENSO Applications Center, the Pacific RISA program, National Weather Service operational services, Pacific regional climate research and climate observations and data management programs will contribute to PaCIS.

The author will also provide an overview of the planned governance and operational structure of PaCIS including a report from the inaugural meeting of the Steering Committee for PaCIS which was held in mid-August 2006. The author will then review the current timeline for initial implementation of PaCIS as a sustained, regional effort designed to support resilient and sustainable Pacific communities using climate information to manage risks and support practical decision making in the context of climate variability and change.

SETTING PRIORITIES FOR DEVELOPMENT OF NEW AND IMPROVED CLIMATE PRODUCTS

Presented by Jim O'Brien, COAPS, FSU

In my opinion, all climate products should be potentially useful for some subset of stakeholders. They must be probalistic forecasts if they are climate products. Error bars should be derived even if these are not always given to the public. Some of the most useful new climate products will be those that are derived from the standard suite of weather variables. For example, at COAPS we issue seasonal estimates of wind roses which are used by engineers and wind power developers. We have developed K/S FIRE forecasts downscaled to counties. The old climate divisions should not be used since they were not derived considering climate. These are other examples will be presented to illustrate possible new climate products.

Making Climate Products Digestible

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Western Regional Climate Center
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Climate products can span a range from simple data listings to complex summaries, and cover the range from past to future. In a significant number of cases, past climate information is being sought for a decision relating to the future, and thus constitutes a de facto forecast. For a large class of users, or potential users, seemingly simple and straightforward factors become the basis for use or non-use. The focus here will be mostly on web-related issues. A well constructed web site will accommodate users with a wide range of technical capabilities and inclinations, and will allow users to "grow" in sophistication and utilize features they originally did not need or understand, or can help them to develop efficient shortcuts. Anything that saves labor, operates easily and rapidly, avoids unnecessary physical movement, and otherwise promotes use and return visitation, without compromising standards, should be considered. Pre-filled forms that anticipate most likely responses speed the interaction. Graphics that are both qualitative and quantitative are preferred. There is often a fine line between emphasis on provider push of potentially useful but unfamiliar material, and the user pull of familiar but perhaps less relevant material. Promoting and allowing room for learning make web pages and software more interesting to users. The use of easily understood but relevant analogies can improve interpretation. For forecasts, track record is important; however, measures of skill that are appropriate to climate scientists may not be the same measures that are appropriate (or else popular or understood) for users. Past episodes where new or emergent phenomenon were successfully forecast are particularly influential. Unlike their daily weather counterparts, climate forecasts verify slowly, as observations become available, and so there is a period where forecasts and observations can be intermingled and sometimes confused. A number of El Nino forecasts seemed to have been bolder in circumstances where verifying observations were trending in the forecast direction. The ultimate importance of developing a supportive constituency for maintaining the research infrastructure should not be underestimated. The associated marketing, salesmanship and presentation all take unexpectedly large amounts of time and resources, but a willingness to commit to this can mean the difference between success and failure as measured in larger terms.

Day 3 & 4 (Sessions 6-7)

Use of reforecasts in diagnosing sources of predictability for week 2 and beyond

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A recently produced ensemble reforecast extending from 1979 to present is used as a tool for understanding sources of predictability for week 2 and beyond. This talk will use reforecasts to examine the relative contributions of tropically forced, versus intrinsic mid-latitude dynamical processes to week 2 forecast skill. Canonical correlation will be demonstrated as a tool for identifying the most prominent predictable patterns and assessing their connection to tropical convective processes during the forecast. Regressions between forecast error and indices of tropical convective patterns (such as the MJO and ENSO) will be demonstrated as a tool to assess how much 'missing' predictability there is due to errors in the representation of tropical dynamics.

Poster Session 1 (Tuesday, October 24, 2006)

CFS Retrospective Forecast Daily Climatology in the EMC/NCEP NOMAD public server

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The new Climate Forecast System (CFS), which is being run operationally out to 9 months on a daily basis at NCEP since August 2004 is regularly used by a large number of users. The usefulness of the CFS forecasts are hampered by the existence of a climate drift in the model which manifests itself in often appreciable systematic errors in many variables. To account for these systematic errors a large set of 4320 retrospective forecasts – the CFS hindcast data set – has been produced. The hindcasts constitute an integral part of the CFS and are used extensively. One of the prime uses of the hindcasts are to produce a monthly climatology that is a function of forecast lead time. This monthly climatology is used, inter alia, to correct the monthly and seasonal forecasts for the systematic errors in the model and to calculate anomaly fields.

It has also been recognized that in many applications there is a need of a daily climatology that is available at all forecast lead times. A smooth daily climatology of the annual cycle has therefore been prepared for a subset of atmospheric and oceanographical variables, in total 42 variables, based on the hindcast data. Since the CFS hindcast data set spans the 24 years from 1981 to 2004, the climatology is based on 24-yrs instead of the WMO standard of 30-yrs.

The methodology used to calculate the climatologies are presented as well as the characteristics of the daily climatologies.

The Impact of Air-Sea Interaction on Tropical Intraseasonal Variability in the CFS

Kathy Pegion [1]
Ben P. Kirtman [1,2]
J. Shukla [1,3]

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The simulation and predictability of tropical intraseasonal variability is compared in long simulations of both coupled and uncoupled integrations of the National Center for Environmental Prediction Climate Forecast System (CFS). The simulation of tropical intraseasonal variability in the coupled and uncoupled models is compared to determine the impact of air-sea interaction. Results indicate that the coupled simulation is better organized, has better eastward propagation than the uncoupled simulation, and correctly simulates the phase relationship between precipitation and sea surface temperature (SST).

Potential predictability experiments are performed for both the coupled and uncoupled models. The model is initialized with intraseasonal events selected from the coupled simulation. The uncoupled experiments are forced with "perfect" SSTs while the coupled experiments are allowed to evolve on their own. Predictability estimates indicate that air-sea coupling provides no additional potential predictability. However, "perfect" SSTs are an unrealistic case. Therefore, predictability experiments with persisted SST anomalies, forecast SSTs, and climatological SSTs are performed to address the sensitivity of the potential predictability of tropical intraseasonal variability to differences in SSTs.

Probabilistic Crop Yield Forecasts using the Upgraded FSU Regional Spectral Model

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Center for Ocean-Atmospheric Prediction Studies, The Florida State University, Tallahassee, FL, USA, 32306-2840

An advanced land model (the National Center for Atmospheric Research Community Land Model, NCAR CLM2) is coupled to the Florida State University (FSU) regional spectral model to improve seasonal surface climate outlooks at very high spatial and temporal resolution and examine its potential for crop yield estimation. The regional model domain is over the southeast United States and run at 20 km resolution, roughly resolving the county level. Warm season (March-September) ensemble simulations are performed to characterize uncertainty in the forecast. Twenty member ensembles of the regional model are generated using different initial conditions and model configurations (i.e., the ensemble methods based on different convective schemes). These ensembles are used to make probabilistic forecasts of the crop yield. Preliminary results will be presented in the workshop.

"**Engaging Climate Prediction Community**
– Momentum from NOAA 4th Climate Prediction Application Science Workshop"

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Interannual and Intraseasonal Variability in the CFS Interactive Ensemble

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A coupled interactive ensemble technique is applied to the National Center for Environmental Prediction (NCEP) Climate Forecast System (CFS) to determine the relative importance of internal atmospheric dynamics and coupled air-sea feedbacks on the interannual and intraseasonal variability in the CFS. Using this technique, multiple atmospheres are coupled to a single ocean. The ocean receives the average flux over all the atmospheres, while each atmosphere is forced by the same SSTs. In this way, the ocean does not "feel" the internal atmospheric "noise". A 30-year interactive ensemble simulation has been performed with the CFS. By comparing this simulation to a non-interactive simulation, we determine the importance of internal atmospheric dynamics to the interannual and intraseasonal variability in the CFS.

Recent Developments in the CPC Experimental Global Tropics Hazard Assessment

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The CPC experimental global tropics hazard assessment is an activity that provides outlooks for regions of enhanced/suppressed rainfall and periods of elevated/suppressed tropical cyclone activity across the global tropics for leads out to two weeks. The activity has participation from both the development and operations branches of CPC as well as the African Desk and includes collaboration from several other areas of NOAA including the National Hurricane Center. The paper will present (1) an overview of the activity with a complete list of contributors, (2) objective verification of the outlooks, (3) recent developments in both production and research, and (4) both short- and long-term goals of the activity. Initial verification results are encouraging and warrant continued development of the product.

Applying Noah LSM in NASA-NCEP Land Information System (LIS) to Provide a Realtime and 25-year Retrospective Global Land Data Base for Climate Model Impact Studies in the NOAA-NCEP Climate Test Bed

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Accurate initialization and physical simulation of land surface states, namely, soil moisture, soil temperature, vegetation, and snowpack, is critical in weather and climate prediction systems because of their regulation of surface water and energy fluxes between the surface and atmosphere over a variety of spatial and temporal scales. For those climate models in the NOAA-NCEP Climate Test Bed (CTB) that execute the Noah LSM as their land component, we seek to provide optimal land-state initial conditions that are both 1) the product of surface forcing that utilizes observed rather than model precipitation and 2) self-consistent with the inherent climatology of the Noah LSM. We achieve this by applying the Noah LSM in the uncoupled, land-component only, Land Information System (LIS, http://lis.gsfc.nasa.gov) developed by NASA and NCEP. In this implementation, the NCEP Global Reanalysis-2 (GR2) and the NCEP Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) are used to drive LIS/Noah for multi-decadal uncoupled land surface simulations executed on the NCEP supercomputer that serves the CTB framework. The latest version of Noah LSM has been coupled to the test bed versions of the NCEP Climate Forecast System (CFS) for climate prediction. It is crucial that the uncoupled LIS/Noah use exactly the same Noah code (and soil and vegetation parameters therein), and execute on the same horizontal grid, landmask, terrain, soil and vegetation types, seasonal cycle of green vegetation fraction and surface albedo, as in the coupled CFS/Noah.

To support CTB, the approximately 25-year (1980-2005) retrospective global land surface states have been generated with LIS/Noah. To study the impact of land initial conditions to CFS seasonal predictability, it is planned to run both the current CFS (with the OSU LSM) and the test bed CFS/Noah with the following land initial conditions: 1) LIS/Noah, 2) LIS/Noah Climatology, 3) GR2/OSU, 4) GR2/OSU climatology, for selected cases of warm and cold seasons for selected years of climate interests. Future plan includes the real time extension and snow assimilation using the Air Force Weather Agency real time satellite-derived global snow analysis.

The importance of stochastic forcing in limiting CFS predictability

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The influence of atmospheric stochastic forcing on the limit of predictability of the CFS is quantified based on comparisons of idealized identical twin prediction experiments using two different coupling strategies. In the first method, called the interactive ensemble, a single oceanic GCM (MOM3) is coupled to the ensemble average of multiple realizations (in this case six ensemble members) of an atmospheric GCM (GFS). In the second method the standard CFS is used. The interactive ensemble is specifically designed to reduce the internal dynamic fluctuations that are unrelated to the SST anomalies via ensemble averaging at the air-sea interface, whereas in the standard CFS, the atmospheric noise (i.e., stochastic forcing) plays an active role in the coupled system.

In the identical twin experiments presented here we take the perfect model approach thereby explicitly excluding the impact of model error on the estimate of the limit of predictability. The experimental design and the analysis separately consider how uncertainty in the ocean initial conditions (i.e., initial condition noise) versus uncertainty as the forecast evolves (i.e., noise due to internal dynamics of the atmosphere) impact estimates of the limit of predictability. Estimates of the limit of predictability are based on both deterministic measures (ensemble spread and root mean square error) and probabilistic measures (relative operating characteristics). The analysis examines both oceanic and atmospheric variables in the tropical Pacific.

The over-arching result is that noise in the initial condition is the primary factor limiting predictability, whereas noise as the forecast evolves is of secondary importance.

Consolidation of Multi Method Forecasts of SST

Malaquias Peña, Huug van den Dool, David Unger, Peitao Peng
NCEP-NWS-NOAA

A performance of consolidation strategies of multi-method ensemble forecasts is presented. The analysis is based on the prediction of monthly SST over the Pacific based on ensemble runs from 9 models: DEMETER, CFS and CA. Consolidation techniques compared include multi-ensemble mean, constrained regressions and double-pass constrained regression. The latter technique is introduced here as an alternative to the ad hoc selection of models. A major problem to test the strategies in a cross-validation framework is the short length of the training data. Since most of the hindcasts are the retrospective forecasts of 21 years (1981-2001), a grid-point by grid-point cross-validated assessment would result in fitting 9 coefficients with at most 20 values. Another complication is the inherent trend in the SST that produces degeneracy when the testing period removed in the cross-validation is one year or a small block of consecutive years. We settled for a three years-out 'random' cross-validation assessment (the test element, and two more at random) and a strategy to increase the effective sample size of the training data by combining information from all the grid-points in the domain of analysis and from each of the ensemble members. Anomaly correlation measures show that constrained regression outperforms the multi-ensemble mean for most of the tropical Pacific and in some parts of the extratropics.

Consolidation of CPC Seasonal Forecast Tools with Ridging Regression Method

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Several seasonal forecast tools, such as CFS, CCA, SMLR and OCN, are being used in CPC for US seasonal climate forecasts. Because these tools have different physical basis or are based on different statistical schemes, their skill scores are quite different in geographical distribution and magnitude. A challenge question is thus raised: is it possible to enhance forecast skill by combining predictions from these different tools? In this study, we are using an objective method to consolidate these forecast tools. The procedure is in two steps. The first step is to assign optimal weights to the de-trended CFS, CCA and SMLR forecasts to have a weighted averaged forecast for inter-annual variability. The second step is to adjust the forecast obtained in the first step with the trend forecasted by OCN. The optimal weights are determined with the multiple linear regression method using the de-trended "historical" model data and observations. The cross validation technique is used to have the training data to be independent from the verification data. The singularity problem of the regression matrix caused by the "co-linearity" of model data is eliminated with the ridging technique. The results of the forecast test for the period of 1981-2005 will be presented and the dependence of the skill improvement onto some parameters will be analyzed. This work is a part of CTB project of "consolidation of CPC seasonal forecast tools" led by Huug van den Dool.

Prospects for Forecast of Cumulative Precipitation at Subseasonal Time Scales over the Sahel with the NCEP Climate Forecasting System: /Assessment of the skill of operational forecast during the 2006 monsoon period

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Forecast of cumulative precipitation over the Sahel area at subseasonal time scales (lead times between 15 and 60 days) during boreal summer is an important target for the potential societal benefits locally and remotely. Additionally, this area provides a test bed for our understanding and modeling of weather and climate due to the complex interactions between the ocean, land surface, ITCZ and the Saharan thermal low. We first show that the NCEP Climate Forecast System (CFS) has useful skill in forecasting cumulative precipitation at subseasonal lead times for the period from 1982 - 2004. We then review the 2006 West African Monsoon and finally we evaluate the skill of forecasts of cumulative precipitation anomalies with the operational CFS during this season.

Phone:

What You Should Know about Correlations for Studies of Climate Variability and Prediction

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It is apparent from papers offered at Climate Diagnostics and Prediction Workshops (CDPWs) and in the published literature that a large number of analysts of climate variability and its prediction lack a working understanding of four topical areas crucial to the effectiveness of their work. The four, all heavily reliant on statistics and statistical theory, include (1) correlations, (2) Principal Component Analysis, (3) confidence limits and statistical significance, and (4) forecast verification. I sensitized a large portion of the climate variability community to the main issues and best practices of topic (2) through a compact overview with key examples at the 30th CDPW. The objective was to help reduce the extensive misuse of eigenvector based tools. At the 31st CDPW my objectives will be the same for topic (1), correlations. The main points and examples along with a handful of easily accessible listed references will form the basis for efficient self-education for all the points addressed, negating the necessity of a cumbersome literature search. Subtopics covered will include definition and types of correlation, comparison of two time series or two maps, the relationships of correlation to regression and linear trend, and autocorrelation and its consequences. The take-away messages will emphasize the interpretation and meaning of correlations and their relevance (or lack thereof) to underlying physics. Topics 3) and (4) both intersect this lecture; in future workshops. I hope to address them more thoroughly.

Predictable Patterns of the Asian and Indo-Pacific Climate in NCEP CFS

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In this study, a maximized signal-to-noise empirical orthogonal function (MSNEOF) analysis is applied to depict the predictable climate patterns over Asia and the Indo-Pacific Oceans. Output from the hindcast experiments of NCEP CFS T62L64 is analyzed. The experiments, conducted for the period of 1982-2004, have 15 ensemble members in each of 9-month integrations.

The CFS is highly skillful in capturing many climate signals associated with El Niño/Southern Oscillation (ENSO). The model successfully predicts ENSO with reasonable amplitude and latitudinal extent of sea surface temperature (SST) anomalies with a lead time of 6 months. The skill for predicting the Asian summer monsoon mainly relies on the effect of ENSO. The most dominant MSNEOF mode of the summer climate is characterized by the climate features during the onset years of ENSO, with strong signals over tropical Asia and the northwestern Pacific. On the other hand, the second mode is characterized by the climate features during the decay years of ENSO, with dominant features in the western Pacific cyclonic or anticyclonic pattern and over the Indian Ocean.

For spring, the CFS predicts SST and precipitation patterns similar to the pattern associated with the North Pacific index and these patterns are predictable in advance by 6 months. The model can also predict the Indian Ocean dipole (IOD), especially for the fall. There exists an apparent difference in the phase transition of ENSO between the CFS and observations. During the ENSO years, the tropical central-eastern Pacific SST anomalies extend too westward, which may explain the stronger than observed IOD in the model especially in the fall.

Towards a Comprehensive Assessment of the Performance of NCEP CFS in Simulating and Predicting the Climate over Asia and the Indo-Pacific Oceans

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The NCEP coupled Climate Forecast System (CFS) has shown substantial skills in ENSO forecast and some skills in predicting the United States climate. However, how the system simulates and predicts the monsoon climate over Asia and the Indo-Pacific Oceans is not immediately clear.

The Asian-Australian monsoon, which is inseparably linked to the coupled atmosphere-ocean-land processes over the Asian continent, the Pacific Ocean, and the Indian Ocean, is an important climate system that drives forcefully the global climate on different timescales. It is argued that accurate simulation and prediction of the Asian-Australian monsoon climate improve the skills of predicting the climate elsewhere.

Several efforts have been made at the NOAA's Climate Prediction Center recently to assess the performance of the NCEP CFS in simulating and predicting the monsoon climate over Asia and the Indo-Pacific Oceans. These efforts have been devoted into understanding the most predictable climate patterns, the lead time of skillful prediction, model bias, and the improvement in the system due to the increase in model resolutions. In this presentation, several major results from the various studies will be introduced and discussed.

Seasonal Precipitation Predictions over North America using the Eta Regional Climate Model

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To assess seasonal prediction using a regional climate model (RCM), in this study we continue our advancement and testing of a high resolution, Eta-model based Regional Climate Model (Eta RCM). In terms of physics, resolution (32-km) and domain size, the version of the Eta model we use is identical to that in NCEP's N. American Regional Reanalysis (NARR), except for minimal model changes to allow longer Eta-model forecast executions on seasonal times. These changes include adding daily updates to the SST fields, sea ice cover, green vegetation cover, and surface albedo.

The substantial extension here with respect to our previously presented Eta RCM studies is our execution of a complete 5-year hindcast of Eta RCM seasonal predictions for the period 2000-2004, plus the two additional years of 1983 and 1999, for both summer and winter predictions. In contrast to many previous RCM studies, in which the RCM is initialized from one single date, we used an ensemble approach in both simulation mode and fully predictive mode. In the classical simulation mode, we apply observed SST and analyzed lateral boundary conditions, in our case from NCEP Global Reanalysis II. In full prediction mode, we apply predicted SSTs and predicted lateral boundary conditions from NCEP's Climate Forecast System (CFS). Our full prediction mode study is one of just a few previous RCM studies carried out in full prediction mode. Previous RCM studies mostly employ the simulation mode or a quasi-prediction mode (which uses predicted lateral boundary conditions but observed SSTs).

For the summer season predictions and simulations, we executed an ensemble of ten Eta RCM runs through September from ten initial dates spanning mid April through early May for each summer of 2000-2004 and 1999. We focus on the Eta RCM and CFS summer prediction for year 1999, which manifested a wet southwest U.S. monsoon. For the winter season predictions and simulations, we executed an ensemble of seven Eta RCM runs through April from seven initial dates spanning mid December to late December for each winter of 2000-2004 and 1983. We focus on the Eta RCM and CFS winter prediction for year 1983, which manifested a strong El' Nino event.

Our main intereste in this study is to what extent the Eta RCM prediction of seasonal precipitation provides improved skill or value-added attributes (such as temporal frequency) relative to the corresponding CFS prediction. The advantage of investing a great effort to execute a multi-year hindcast, such as the 2000-2004 hindcast here, is that model predictions can be cast in terms of anomalies with respect to the model's own climatology, thereby mitigating the effects of model systematic errors and biases.

A successful story in predicting NAM events by the operational NCEP's GFS model.

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It is customary to assume a two-week limit of predictability for weather in the earth's atmosphere. However, there are some exceptions. For example, atmospheric anomalies forced by external boundary conditions may survive much longer than 2 weeks. The QBO in the stratosphere has to be predictable over many months if not years. Here we report that the annular mode, a dominant low-frequency mode in the atmosphere, can be predicted remarkably well beyond a week by the NCEP's high resolution GFS model (T382L64).

The predictive skill of the Northern Annular Mode is examined using RMS (root mean square) error, AC(anomaly correlation) and bias for the period from September 2005 to March 2006. The model forecast in the stratosphere shows scores above 0.8 level in terms of AC skill (except for the rapid phase transition time) until the end of forecast at day 16, which is comparable to skill in the troposphere at about day 7. In the polar troposphere, the model prediction is well above the persistence forecast with up to 0.35 extra AC skill for the 1st week but deteriorating very quickly afterwards. From week_1 to week_2, the model's skill is nearly as bad as the persistence except in the polar stratosphere. In the polar stratosphere, the model forecast gradually becomes better than persistence in the 1st week, and tends to maintain the extra 0.28 AC skill over persistence in the 2nd week. We found evidence that the extra skill in the 2nd week in the polar stratosphere is due to the model's ability to capture poleward propagating anomalies. It is seen that large amplitude anomalies over the polar stratosphere are mainly originated from the tropics and it takes several weeks for them propagate into high latitudes. Therefore, having the signal in low/mid latitudes to begin with in the model initial state helps the model to predict the polar stratosphere circulation anomalies beyond the traditional predictability by the dynamic model.

From our results, it appears that some aspects of atmospheric variability are not only predictable, but also already well predicted by current models.

NCEP REGIONAL CLIMATE FORECAST BY NCEP RSM MODEL

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For a decade, regional forecast models have been implemented to conduct seasonal forecasts. An experiment using NCEP RSM model has been carried out to produce 7 month ensemble regional climate forecast on CONUS. The global model is CFS (T62L28), and the resolution for NCEP RSM is 50km. The experiment has two modes, hindcast mode which contains 23 years hindcast, and forecast modes which started from Oct 2004.

Because the regional climate forecast produced by this experiment will be used as input to fire danger index model, the results are analyzed for east, middle and west regions in the Unite State to compute the forecast scores and to explore the effect of local features such as orography. Extreme events including 1982 winter ENSO and 1999 monsoon event are also analyzed. The differences between global model (GSM) and RSM model in the three different regions are presented and the causes for these differences are investigated.

Statistics related to the merging of short and long lead precipitation predictions in the continental U.S.

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It is increasingly common for producers of seasonal hydrologic prediction products (such as water forecasts and drought outlooks) to consider short lead precipitation forecasts from a variety of sources while forming their longer lead outlook products. The merging of the short lead information with longer lead precipitation indicators from other sources is often qualitative, suggesting a need for quantitative approaches for weighting forecast information at different lead times in generating the longer lead products. A preliminary step in understanding the relative merits of combining forecast information at different lead times is to explore statistics (such as anomaly correlation) derived from relating precipitation from an initial short forecast period (e.g., from 3 to 15 day) to precipitation during a longer period continuing from (and including) the short period (e.g., out to 3 or 6 months). This relationship is assessed using daily precipitation records from 2130 stations across the continental US, for various combinations of 1, 2, 3, 4, 7, 10, and 15 days, and 1, 2, 3, 6, 9, and 12 months, for start dates in each week of the year. As expected, the results show large variations in the importance of the short initial period precipitation for estimating precipitation over longer periods, depending on time of year and region. They suggest, for example, that a 7-day lead prediction alone may have limited utility in determining a 3-month outlook outside of California and parts of the Southwest from February through June, or in the central tier of the US during autumn. These and other notable results of the analysis are presented.

Sea ice for NCEP Climate Forecast System

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Sea ice is an integral component of the global climate and weather system. The extent of sea ice is mainly influenced by, and has a significant effect on, the surface energy budget, the ocean-atmosphere energy exchange, and the ocean fresh water balance. In this work we investigate the sensitivity of a sea ice model which is coupled to MOM4 for NCEP Climate Forecast System (CFS). For the sea ice model, the ice dynamics is based on Hunke and Dukowicz (1997) and the ice thermodynamics is based on Winton (2000). During the spin-up phase (100 years) the coupled MOM4 and ice model was forced using NCEP reanalysis-2 (R2) climatology. The sea surface temperatures (SSTs) are relaxed to Levitus climatology with a 5-day time-scale and sea surface salinity (SSS) with a 10-day time-scale. After the spin-up the coupled model was then forced with R2 6-hourly and daily mean forcing (using short wave and long-wave radiations, precipitation, 2m temperature and moisture, and 10 m wind) from 1981 to 2004. For the R2 forcing no SST or SSS relaxing was applied. The simulated sea ice distribution from the coupled model is reasonable, although too little sea ice is simulated in summer (for both coverage and thickness) and sea ice concentration is a bit too high relative to the satellite observation in winter. For the ocean the warm and cold phase of SST over Equatorial Pacific is reproduced. The (warm) SST bias (over mid-latitudes) is reduced when 6 hourly forcing is used instead of daily forcing. The coupled MOM4-sea ice model will be coupled to NCEP Global Forecast System to form the next upgrade of the NCEP CFS.

Evaluation on the simulation of MOM4 coupled to an ice model

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The current generation of Geophysical Fluid Dynamic Laboratory (GFDL) Modular Ocean Model (MOM4) is coupled to an ice model to examine its simulation and the impact of resolution and forcing frequency. The ocean model has a global domain and is configured in two different horizontal resolutions: regular resolution and high resolution. The regular resolution has a 1°x1° degree in extra-tropics gradually increased to 0.33°x1° degree in the tropics which is a typical setting for the most of the current ocean models. The high resolution has a 0.5°x0.5° degree in extra-tropics gradually increased to 0.25°x0.5° degree in the tropics. Vertically both of the settings have 40 layers with 10 meters depth in the first 20 layers. The ocean physics consists of KPP vertical mixing scheme, Gent-Mcwilliams isoneutral tracer mixing, an explicit free surface and freshwater fluxes. Shortwave radiation penetration is calculated from Morel and Antoine (1994)'s optical model which takes account of the chlorophyll concentration. The impact of runoff effect is also included in the model.

The model is initialized from Levitus 2001 annual mean climatology of temperature and salinity for 40 year with monthly wind forcing, surface heat and freshwater fluxes from NCEP/NCAR Reanalysis II data set. Then it is forced with reanalysis II daily and 6 hour forcing from year 1981 to 2004. Results show that both regular and high resolution runs captured the main features of the ocean state from climatological mean to inter-annual variability. The high resolution run yields more realistic Kurishio and the Gulf streams which are the key region to distribute the warm water to middle-latitude. The inclusion of the runoff process helps to maintain the low salinity water near the shallow coast region. The comparison between daily forcing and 6 hour forcing indicates high frequency forcing helps to reduce the Sea Surface temperature (SST) bias particular in extra-tropics.

This model setting will be coupled to NCEP Global Forecast System (GFS) to form the new generation of NCEP Climate Forecast System (CFS).

Seasonal Cycle of the Upper Tropical Pacific Ocean in Global Ocean Data Assimilation Systems

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Seasonal cycles of the upper tropical Pacific Ocean have not been well documented and understood due to sparse observations both in space and time, particularly for currents in the open ocean. However, sophisticated global ocean data assimilation systems (GODAS) are developed to optimally combine model solutions with sparse observations to give best estimations of the state of the ocean for the past 20-50 years. Despite of significant improvements in GODAS ocean reanalyses around the world, it is not clear whether the most updated ocean reanalyses are accurate enough to be used to document the seasonal cycles of the tropical Pacific. So a few GODAS ocean reanalyses, including the newly available GODAS of the National Centers for Environmental Prediction (NCEP), the Simple Ocean Data Assimilation (SODA, version 1.4.2) of University of Maryland-College Park and the ENhAnced ocean data assimilation and ClimaTe prediction (ENACT) of the European Centre for Medium-Range Weather Forecast (ECMWF), and the observational-based analysis of the World Ocean Atlas 2006, that contains large amount of new data from the Southern Hemisphere beyond that of WOA2004, are used to derive a best estimation of the seasonal cycles as well as deficiencies of each model in simulating seasonal cycles.

Previous estimations of the seasonal cycles of the tropical Pacific are mostly derived from subsurface thermal fields. In this study, we not only analyze the seasonal cycles of oceanic temperature, but also those of oceanic circulation and associated physical processes. Particularly, we analyze the seasonal cycles of equatorial currents, subtropical circulation cells, mixed layer depth, 20ºC isotherm depth, upper 300 m heat content, and warm water volume whose temperature is higher than 20ºC. The seasonal variations in warm water volume is further associated with the charge-discharge of the tropical water across the boundaries (about 10ºN and 10ºS) of the tropical and subtropical gyres. The detail pathways and seasonal variations of water mass exchanges from the subtropics to tropics are quantified using isopycnal analysis.

The best estimation of the seasonal cycles can have a broad application including identifying model biases and understanding interactions between the seasonal cycles and interannual and longer timescale variability.

Evaluation of CFS-tier2 forecasts with bias-corrected SST

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As a transition project of CTB, a series of experimental forecast runs were made with the atmospheric component of the NCEP CFS coupled GCM and bias-corrected SST forecasts from the CFS hindcast runs. The primary objective is to assess the impact of improved SST forecast on seasonal climate prediction. The hindcast runs have been expanded to include initial conditions in the months of January, April, July and October, and the assessment on the impact of the bias correction based on these runs will be reported at the workshop.

Poster Session 2 (Wednesday, October 25, 2006)

Timescale-Dependent Characteristics of U.S. Precipitation Anomalies

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In this study, we have analyzed the most dominant modes of the United States precipitation using monthly, seasonal, and annual mean data from both observations and the NCEP coupled Climate Forecast System. We have focused on the timescale- and season-dependent features and the physical mechanisms of the U.S. precipitation variability.

Empirical Orthogonal Function analysis and wavelet analysis have indicated that the variability of precipitation of different timescales posses different loadings of spatial patterns. The dominant patterns of different timescales are linked to patterns of sea surface temperature and atmospheric circulation in different ways. Comparison of observations with model results and analysis of the time-lag relationship between precipitation and SST provide useful information to assess the predictability of the U.S. precipitation, for the various seasons, by identifying potential predictors for different timescales in different locations.

An Analysis of Global Land Monthly Precipitation Climatology Using Gauge Observations and Satellite Estimates

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Pingping Xie (Climate Prediction Center, NOAA/NWS/NCEP)
John E. Janowiak (Climate Prediction Center, NOAA/NWS/NCEP)
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Toward the construction of a global monthly precipitation climatology with improved representation of orographic effects, preliminary work has been conducted to compare two sets of precipitation climatologies, to explore the relationship between precipitation enhancements and local orography, and to develop a prototype algorithm to create monthly climatology over the global land with orographic consideration.

First, two gauge-based precipitation climatologies, the PRISM of Daly et al. (1994) and the PREC/L of Chen et al. (2002), are compared over a 0.5^{o} lat/lon grid over the contiguous United States to examine how orographic enhancements in precipitation may impact the quantitative accuracy in the interpolated precipitation fields over mountainous areas. In the PRISM, the monthly precipitation climatology is calculated via a rainfall – elevation relationship that has been established empirically for each calendar month by local comparisons, while in the PREC/L it is defined by an inverse-distance interpolation of gauge observations with no orographic considerations. While good agreement in both quantitative magnitude and spatial distribution patterns are observed between the two climatologies over areas with relatively flat terrain, significant underestimates are reported in the PREC/L compared to the PRISM over the mountainous areas in the western United States. Quantitative examinations of the two climatologies over the mountainous areas reveal a clear relationship between the departures in precipitation climatology and the grid box elevation, implying that the differences between the PREC/L and the PRISM are related to differences in the manner in which orographic effects are handled.

To understand how precipitation is influenced by topography, the relationship between the monthly station precipitation climatology and station elevation is examined statistically using the GHCN Version 2 data set. Orographic enhancements in precipitation are observed over all mountainous areas examined in this study. In a selected region, the monthly precipitation climatology at a station increases with its elevation at a rate that differs for different seasons and for different locations relative to the wind direction. This rate of orographic enhancement in precipitation, however, can be expressed very well as a linear function of the mean precipitation over the region regardless of season and relative location. The existence of this linear relationship is confirmed for all of the regions examined in this study, but the coefficients in the relationship differ regionally.

Based on these results, a prototype algorithm is being developed at NOAA Climate Prediction Center (CPC) to construct a monthly precipitation climatology over the global land areas with improved representation for orographic enhancements in precipitation by combined use of gauge and satellite observations. Gauge-observed monthly precipitation climatology is defined for over 30,000 stations using data collected from the Global Historical Climatology Network (GHCN) of NOAA/NCDC, Climate Anomaly Monitoring System (CAMS) of NOAA/CPC and several other data sets acquired through various CPC activities. Monthly precipitation climatology derived from the TRMM Precipitation Radar (PR) and SSM/I Passive Microwave (PM) observations are defined for an 8-year period from 1998 to 2005. The raw satellite-based precipitation climatology is then adjusted against the gauge-based climatology to remove large-scale bias. The gauge station climatology and the bias-corrected satellite data are finally combined through an optimal interpolation (OI) – based technique, in which analyzed precipitation climatology is dominated by gauge observations over locations with dense gauge networks, while over gauge sparse areas its spatial distribution is controlled by satellite observations and its magnitude is influenced by nearby gauge data with topographic consideration. Details of the algorithm and the resulting precipitation climatology will be reported at the meeting.

**Variability of Daily Precipitation over South America:
Data and Applications**

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A state-of-the-art daily precipitation analysis for South America for the period 1978-2004 has recently been developed in CPC and is used to examine the annual cycle and variability of daily precipitation over the continent. Emphasis is placed on daily precipitation statistics (including frequency of occurrence, intensity and geographic distribution). The NCEP/NCAR Reanalysis is used to examine the large-scale circulation features associated with extreme precipitation events.

Exploring a Dipole in Caribbean and Pacific Heat Storage That May Modulate TC Activity and Intraseasonal Rainfall Variability in the NAM

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With the recent changes in AMO and PDO regimes, there appears to have been an increase in the intensity and duration of mid-summer drought (Canicula) in Mexico associated with an increase in Atlantic TC activity at the expense of TC activity in the East Pac. Midsummer drought is a normal phenomena in eastern and southern Mexico, yet not all years have a pronounced mid summer drought. The most recent hypothesis concerning this phenomenon has been that the midsummer dry spell (Canicula) develops in response to cooling of surface waters in the East Pac following a period of strong activity in the ITCZ. Anomalous warm SSTs are believed to trigger the activity which then dies due to negative feedback mechanisms (see Magaña et al. JCLIM 1999). In looking more closely at the data, when the East Pac is anomalously warm in May, subsequent monthly SST anomalies do not show strong cooling periods (active ITCZ) followed by warming (weak ITCZ) per the Magaña hypothesis.

Our preliminary work suggests that the development of mid-summer drought may be linked to a see-saw in the primary seat of warmest water between the east Pacific and the Caribbean prior to the start of the NAM. This see-saw may impact the character of the TC seasons in the East Pac and Caribbean with sensitivity to both SST anomalies and heat storage. There is considerable year-to-year variability in monthly TC numbers in the East Pac. When East Pac TC activity is above normal in July, rainfall is also above normal, but if the active July is followed by a weak August, rainfall drops off to below normal levels, but the two month rainfall totals remain slightly above normal. If East Pac TC activity is low in July, and then high in August, southern Mexican rainfall tends to be very low in July, with August rainfall totals tending not to offset the deficits of July. These TC-rainfall relationships may be tied to variability in the SSTs and heat content of the two warm water pools of the East Pac and the Caribbean.

The Atlantic Dipole Mode and Recent Flooding over West Africa

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West Africa experienced extremely heavy rains over portions of the Sahel during the period from June to October 2005. The rainfall season in the far western end of the Sahel was the wettest in over 30 years. This paper examines the physical processes associated with the unusually wet West Africa rainfall seasons and the extreme dryness in East Africa with emphasis on the role of the Atlantic dipole mode on the synoptic features.

The rainy season in West Africa was marked by highly frequent heavy rainfall episodes resulting from very active African wave disturbances. Rainfall amounts were over 50% above the climatological mean in many areas resulting in flooding over Senegal and an increase in infectious disease outbreaks mainly cholera and malaria. This marks a sharp contrast from the long term drying trend that started in the mid-70s and continued into the 80s and the 90s. Over the past 3 years, though the coupled ocean-atmosphere system featured circulation patterns similar to those observed in the 50s and more favorable to enhanced convection. This so called "rainfall recovery" in the Sahel is discussed. In particular, during the period from May to August, the prominent Atlantic dipole mode characterized by a cold Gulf of Guinea and a warm north Atlantic was well in place. The physical processes associated with this mode of variability which is more prominent on the decadal time scale and its influence on the synoptic features that resulted in a very active West African monsoon season is discussed. Finally, an evaluation of the NCEP coupled forecast system (CFS) in depicting the 2005-2006 extreme events is examined.

How Important is Air-sea Coupling in MJO Evolution?

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The impact of air-sea coupling upon predictability of weekly mean sea surface temperatures (SST) and atmospheric circulation and diabatic heating in the Tropics is investigated in a linear inverse model (LIM) derived from the observed simultaneous and 7-day lag correlation statistics of weekly averaged SST, streamfunction, chi, and diabatic heating for the years 1982-2003. The LIM accurately reproduces the power spectra of the data, including both intraseasonal and interannual spectral peaks, and similarly reproduces 0 through 90-day lag covariability of all the model variables.

The importance of air-sea coupling is investigated in the LIM by deleting the relevant portions of the linear dynamical operator. It is found that the eigenmodes of the uncoupled operator are quite different from eigenmodes of the coupled operator on interannual timescales but are almost unchanged on intraseasonal timescales. Thus, coupling SST to the atmosphere has a notable impact on interannual variability but only a minor effect upon intraseasonal variability, acting to slightly lengthen propagation and persistence timescales. Some parts of the MJO evolution that are relatively more sensitive to coupling are also presented.

Scale Interactions within the Madden-Julian Oscillation

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It is generally agreed that simulation of the Madden Julian Oscillation (MJO) is crucial for reliable numerical forecasts of week 2, ENSO, and beyond. It is also well-known the "envelope" of the MJO is often comprised of Kelvin, westward- inertio gravity, and mixed Rossby gravity waves, and these in turn are comprised of a broad spectrum of mesoscale features not necessarily organized into "waves". This suggests a dominance of both upscale and downscale interactions in the organization of tropical convection. It seems evident that the MJO modulates the occurrence of smaller scale, higher frequency disturbances, but the mechanisms responsible for this modulation are not yet fully understood. Since two different MJOs that behave in similar ways can be composed of an entirely different suite of equatorial waves and mesoscale features, evidently the upscale interactions can be enabled by a wide variety of disturbances. Understanding the precise role of these scale interactions appears to be a crucial step towards the improved simulation of equatorial disturbances in models.

A potential aid to the understanding of scale interactions is the fact that there is a certain degree of "self-similarity" in observed gross features of the dynamical structures of organized tropical convection, from the mesoscale on up to the planetary scale structure of the MJO. Convectively coupled disturbances universally exhibit strong vertical tilts in their wind, temperature, moisture, vertical velocity and diabatic heating fields. In general these disturbances display a warm lower troposphere ahead of the wave, with cooling behind, and a warm mid-troposphere within the convective region. Low level moistureand thus CAPE and moist static energy is high ahead of the waves, and drying occurs first at low levels while it is still moist aloft behind the wave. Low level diabatic heating precedes deep convective heating, followed by a signal of upper tropospheric heating over cooling. These dynamical signals are consistent with the observation that the waves show a progression from a dominance of shallow to deep convection, and then stratiform precipitation, regardless of scale or propagation direction. It is a remarkable fact that the temporal and spatial evolution of mesoscale convective complexes, which can be traced back to microphysical arguments, also exists at a certain level on the scale of the MJO. These observations have implications for the simulation of convectively coupled waves. Some numerical prediction models appear to have peaks in their rainfall spectra corresponding to the observed spectra of tropical cloudiness. However, all of the waves identified in models thus far have corresponding equivalent depths that are universally too deep and therefore phase speeds that are too fast. These waves all scale to around the same equivalent depth, a fact which perhaps provides clues to the deficiencies of physical parameterizations involved. Simple modeling and cloud resolving studies are beginning to provide some realistic results, and will no doubt provide useful testbeds for the development of improved parameterizations in next generation GCMs.

The relationships between MJO and extra-tropical atmospheric circulation and climate in Japan

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The objective of this study is to examine the relationships between Madden-Julian Oscillation (MJO) during extended boreal winter season, from November to March, and extra-tropical atmospheric circulation and climate, especially focusing on those in Japan, through statistical analysis technique and to build a conceptual model illustrating that relationship. The conceptual model is expected to assist seasonal weather forecasters in comprehensively understanding and appropriately interpreting outputs of numerical analysis and forecast models with regard to the relationship between MJO and the atmospheric circulation.

In this study, the relationships between MJO and extra-tropical atmospheric circulation were examined by composing 20-70-days bandpass-filtered daily mean Japanese reanalysis data (JRA-25) and outgoing longwave radiation (OLR) for each of 12 MJO phases. MJO phases are defined by two indices derived from the projection of 20-70-days bandpass-filtered daily mean 200-hPa velocity potential averaged between 20N-20S, onto its first and second leading empirical orthogonal functions (EOFs) which are calculated for years 1979-2003. According to composites, it is shown that when square root of the indices is above one, that is, MJO is clear to some extent, the features with 95 % or more statistical confidence level of Asian jet, quasi-stationary Rossby wave propagation and the activity of synoptic-scale disturbances across Eurasian continent and the Pacific vary from phase to phase. As a result, climate in Japan also vary for each MJO phase. Especially, the frequency of remarkably heavy rain on the Pacific side of Japan depends on MJO phases. It is suggested from those results that the monitoring and predicting of MJO are important in conducting long-range forecast for Japan as well as for the tropics which is directly influenced by MJO.

On the day of presentation, I'm going to present the conceptual model and the comparison between the results using JRA-25 and those using NCEP/DOE reanalysis data and to discuss possible dynamical processes of the influence of MJO on the extra-tropics.

Modulation of Diurnal Cycle of Tropical Convective Clouds by the MJO

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The infrared cloud amount from the International Satellite Cloud Climatology Project D1 cloud product, in combination with the Tropical Rainfall Measurement Mission 3B42 precipitation product, are employed to study the impact of the Madden-Julian Oscillation (MJO) on diurnal cycle of tropical convective clouds. This analysis is based on the composite of 18 MJO events during seven boreal winter seasons from January 1998 to April 2005 and covers the Indo-Pacific warm pool and the Indian Ocean, where MJO convective activity is greatest. Our analysis demonstrates that the diurnal cycle of tropical deep convective cloud amount (DCC, with cloud tops above 180 hPa) over both land and water is enhanced during the convectively active phase of the MJO, while it is reduced during the convectively suppressed phase of the MJO. The MJO impact on the diurnal amplitude is weakest over the western Pacific and the islands of the Maritime Continents (around 20% of the mean diurnal amplitude) and largest over the eastern Indian Ocean (around 50% of the mean diurnal amplitude). However, the diurnal phase of DCC seems to be unaffected by the MJO.

Similarly, the diurnal cycle of the tropical high clouds (with cloud tops above 440 hPa) over both land and water is also enhanced during the convectively active phase of the MJO, while it is reduced during the convectively suppressed phase of the MJO. In contrast, the diurnal cycle of the tropical low clouds (with cloud tops below 680 hPa) is reduced during the convectively active phase of the MJO, while it is enhanced during the convectively active phase of the MJO. The diurnal cycle of low clouds at different phases of the MJO is similar to the diurnal cycle of SST documented by the TOGA COARE.

Finally, the impact of the boreal summer intraseasonal oscillation on the diurnal cycle of the monsoonal convective clouds is also analyzed. The difference and/or similarity between the boreal winter and summer seasons will be discussed.

Extreme events and hazards in California during winter and the Madden-Julian Oscillation

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This study investigates the importance of the Madden-Julian oscillation (MJO) in modulating the occurrence of extreme events and hazards in California during winter. Outgoing longwave radiation and NCEP/NCAR reanalysis (1979-2005) are used to characterize the occurrence of the MJO during winter. Extreme events in precipitation, temperature and surface wind speeds in California are diagnosed with North American Regional Reanalysis for the same period. Winter hazards are identified with the National Climatic Data Center–National Weather Service Storm Data. Storm Data is an official NOAA publication and documents the occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property/crop damages, and/or disruption to commerce. Events were geographically recorded by State counties or NWS forecast zones. Focus is given to hazard events which are typically observed during the winter season over California such as wind storms, heavy precipitation and snow fall, flooding, coastal erosion, coastal flooding and excessive cold temperatures. An analysis is presented to assess conditional probabilities of hazard events given that extreme events in precipitation, temperature or wind speed will also occur. The presentation will also discuss the benefits of monitoring and forecasting the MJO and its potential influence on winter hazards in California.

Boreal winter links between the Madden-Julian Oscillation and the Arctic Oscillation

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There is increasing evidence that the Madden Julian Oscillation (MJO) has a notable impact upon the mid-to-high latitude circulation. In particular, it appears the MJO has a relationship with the leading mode of extratropical variability, the Arctic Oscillation (AO). In this study, new insights into the observed similarities between the MJO and the AO are explored.

It is shown that the eastward progression of the convectively active phase of the MJO is associated with a corresponding shift in the tendency of the AO index. Moreover, the AO and the MJO share several analogous features not only in the global circulation but also in surface temperature fields. Also, the AO is linked to a pattern of eastward propagating MJO-like variability in the tropics that is approximately reproduced in free runs of the NCEP CFS model. Finally, it is shown that the structure of the AO in the geopotential height field significantly varies based on the phase of the MJO.

Subseasonal to seasonal rainfall variability and atmospheric thermodynamic structures within the West African monsoon system

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Seasonal variations in surface rainfall and 3-dimendional atmospheric thermodynamic structures related to the West African monsoon system are quantified using the TRMM rainfall and AIRS products. Major rainfall events tend to be concentrated in two regions and appear in two different seasons, manifesting an abrupt shift of the mean rainfall zone during June-July. (i) Near the Gulf of Guinea (about 5^{o}N), intense convection and rainfall are seen during April-June and roughly following the seasonality of SST in the tropical eastern Atlantic. (ii) Along the latitudes of about 10^{o}N over the interior West African continent, a second intense rainfall belt begins to develop from July and remains there during the later summer season. Evident seasonal changes are also shown in the 3-dimensional temperature and moisture fields. Seasonal (northward) encroachment of water vapor in the lower and mid- troposphere is clearly shown along with the seasonal march of the major rainy zone (ITCZ). This tends to suggest a different large-scale environment for convective systems within the ITCZ during boreal summer from that for those along the coastline during boreal spring.

Variations of vertical profiles of potential temperature perturbation and relative humidity at daily time scale suggest that convective systems along the coastline during boreal spring may be totally different from those within the continent during boreal summer. Shallow convection or warm rains are frequently observed over ocean or near the coastline; in contrast, deep, high convective systems are dominant over land, followed by evident upper-level moistening. This is generally consistent with the conclusions derived from the TRMM Precipitation radar (PR) measurements.

Impact of Different Boundary Conditions on the Predictability of Tropical Intraseasonal Variability (TISV)

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The possible impact of different boundary conditions on the predictability of Monsoon Intraseasonal Oscillation (MISO) has been studied with a coupled atmosphere-ocean model. From a 15-year coupled control run, two MISO events are selected as forecast targets. A series of 10-ensemble runs have been conducted to predict these two events started from four phases (the number of total forecasts for one boundary condition, N=2*4*10=80) and under four different boundary conditions: i) fully atmosphere-ocean coupling; ii) "smoothed" SST from the coupled control run; iii) damped persistent SST and iv) a simple mixed-layer ocean.

For these two particular MISO events, the fully coupled atmosphere-ocean model has highest predictability that reaches about 27 days averaged in the Asian-western Pacific region (10^oS-30^oN, 60^oE-160^oE). The atmosphere-only model forced with "smoothed" and damped persistent SSTs has lowest predictability (~19 days). Introducing a simple mixed-layer ocean into the atmospheric model could extend the predictability by about 5 days.

Finally, we found that if the ensemble-mean instead of the individual ensemble is used to assess the predictability, the predictability will be extended by another 6-10 days for all boundary conditions. The resultant predictability for the fully coupled model, therefore, reaches about 40 days averaged in the Asian-western Pacific region. These findings suggest that fully atmosphere-ocean coupling will produce the best boundary condition for the MISO prediction. Including a simple mixed-layer ocean also increases the predictability compared to the atmosphere-only model forced by the "smoothed" and damped persistent SSTs.

Upper Air Temperature Variations in the Early XXI Century: Do the Updating Time Series and Varying Statistical Techniques Change the Trend Estimates?

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Radiosonde and MSU satellite data, on temperature anomalies in the troposphere and lower stratosphere for the globe and hemispheres, extended till September 2005, are studied and compared. The main question is whether the extending the time series by the quasi-up-to-date data, changes the estimates of temperature trends. This issue is important because, first, the time series of U/A temperature variations are relatively short, and, second, the end of XX century and early XXI century demonstrated many outstanding values in the surface temperature records.

The numerous statistical parameters of the series, including robust statistical parameters, are assessed. Several robust regression statistical techniques are used as alternatives to the ordinary least square (OLS) regression techniques. The main conclusion is that the main features of the time series are preserved, but some differences appear as the longer series (ending in 2005), rather than shorter series (ending in 1998), - are assessed. The existing differences are assessed, and their possible explanations are discussed.

Decadal Changes in East Asian Summer Monsoon Circulation after the mid-1990s

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The authors suggest evidences for a climate shift after the mid-1990s in summertime circulation and its possible dynamics. The East Asian summer monsoon has a large interdecadal variability as well as interannual variability. Previous studies suggested that there was an interdecadal transition in East Asian summer monsoon after the late-1970s (e.g., Hu, 1997; Wu and Wang, 2002). Here the authors suggest that the East Asian summer monsoon has undergone a decadal change in the mid-1990s. There has been a significant decrease in the strength of zonal winds near the subtropical jet in East Asia after the mid-1990s. Also, a distinctive increase in precipitation in the southeastern part of China after the mid-1990s. This circulation change can be understood as a barotropic response to a steady divergence forcing. In other words, the increase in precipitation can be the cause that triggered the circulation change after the mid-1990s.

This precipitation increase seems to be related to the typhoon activity in the western Pacific. Sea surface temperature has increased in the equatorial western Pacific in recent decades. As a result, it is expected that the typhoon activity will become more rigorous in the western Pacific. As a matter of fact, there has been a remarkable increase in the number of the typhoon passing through the southeastern part of China, where precipitation increased significantly after the mid-1990s. It implies that the typhoon activity plays an important role in the precipitation increase in the southeastern China after the mid-1990s. Decadal changes after the mid-1990s are also found in other region as well as East Asia in summertime.

Acknowledgements

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HYPOTHESIZED PHYSICS OF THE ATLANTIC THERMOHALINE CIRCULATION (THC) OR AMO

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The Atlantic multi-decadal oscillation (AMO) is the name that has recently been given to the 25-30 year variation in North Atlantic SSTA and major Atlantic basin hurricane activity. This multi-decadal variation is hypothesized to be a response to multi-decadal variations in North Atlantic ocean salinity – the so called Atlantic thermohaline circulation (THC) or salt oscillator.

This talk will present a hypothesis as to the physical processes which cause these multi-decadal cyclic variations and why and how Atlantic basin major hurricane frequency is strongly modulated by this oscillation. A critique of recent Atlantic hurricane papers comparing AMO and hypothesized global warming influence will also be given.

A Time-slice Global Warming Experiment: Possible Future Impact on East Asian Summer Monsoon

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The global time slice approach is a transient experiment using high resolution atmosphere-only model with boundary condition from the low resolution globally coupled ocean-atmosphere model. Such experiments are aimed at overcoming the difficulty of exploring all sources of uncertainty in future climate projections from computationally expensive and transient climate change simulations using coupled ocean-atmosphere model. Although the previous studies have indicated a significant increase in monsoon rainfall with increasing amounts of greenhouse gases (GHGs), the regional distribution of the precipitation anomalies is still very poor and highly model dependent. In the present study, the response of the East Asian summer monsoon to increasing amounts of GHGs and aerosols is analyzed by employing this "time slice concept" using ECHAM4 atmosphere-only model (Roeckner et al. 1996a) at a horizontal resolution of T106 (corresponding to a grid of about 125 km) with the lower boundary forcing (i.e., SST and sea ice) obtained from a lower-resolution (T30) greenhouse gas + aerosol forcing experiment (GHGs) performed with the ECHO-G/S (ECHAM4/HOPE-G) coupled model. In order to assess the impact of horizontal resolution on simulated East Asia summer monsoon climate for two climate states, namely, the present and a projected one around the time of effective CO_2 doubling (referred to as "future climate" hereafter), the differences in climate response between the time-slice experiments of present and future and that of coarser (T30) coupled model are compared. In addition, present climate simulation with higher-resolution (T106) using observed SST & sea ice have been also produced to consider the model deficiency. We defined the northern hemisphere summer as June, July, August, and September, present climate as 1978~2000, and future climate as 2078~2100. The performance of the higher resolution model in East Asia region, the changes due to doubling greenhouse gases, East Asia summer monsoon driven by lower and higher resolution models, and the plausible change of the East Asia summer monsoon from the present to the future are investigated.

Roeckner E., K. Arpe, L. Bengtsson, M. Christoph, M. Claussen, L. Dümenil, M. Esch, M. Giorgetta, U. Schlese, U. Schulzweida, 1996a: The atmospheric general circulation model ECHAM-4: Model description and simulation of present-day climate. MPI-Report 218: pp90

Title: Understanding wintertime surface temperature trends over Asia and North America during 1950-2000

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Observations show a significant increase in surface temperature during the second half of the 20th century. Asia and northwest North America particularly experienced strong surface warming during northern winter. This study investigates the causes of the wintertime surface temperature trends over Asia and North America during 1950-2000, and evaluates the relative roles of global warming and decadal variability. Estimates of the climate changes over 1950-2000 are compared in a number of products including GHCN station observations, NCEP/NCAR reanalyses, ERA40 reanalyses, and several AMIP simulations with various AGCMs. The observed warming trend over northwest North America is generally well reproduced in both reanalyses products and AMIP simulations, whereas the observed warming over Asia is evident in reanalyses, but not in the AMIP simulations. A series of AGCM experiments forced by idealized SST anomalies associated with various combinations of the global warming and decadal variability modes are performed. Results show that the surface warming over Asia appears to be linked to the global warming signal in tropical Indian Ocean, whereas the surface temperature trend over North America is primarily attributable to the decadal SST variability in the Pacific.

A Case Study of Temperature Trends across the United States

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Since official record keeping began in the late 1800s, temperature has shown marked variability across the United States. Based on average temperature, a majority of stations have experienced a warming trend, particularly over the most recent twenty years. However, from station to station, the average temperature trends have shown large differences. Most notably, some locations have shown major warming with respect to minimum temperature, while showing little if any warming of maximum temperature. At these sites, there has been a significant reduction in the diurnal temperature range (the difference between the maximum and minimum temperature). One common factor among such stations is that they are located near a growing population center. In contrast, those located farther from a population center either do not exhibit this trend, or show it with a much weaker signal.

The National Climatic Data Center (NCDC) in Asheville, NC has developed several “climate divisions” across the nation. These divisions are typically about half of the size of a state and are comprised of all official stations within the area, including those designated as first order stations. Even within a particular climate division, the temperature trends exhibit major differences, primarily with minimum temperature. Temperature trends also show a great deal of variability regionally and seasonally. Different regions of the country show unique trends, with the intermountain west exhibiting the greatest discrepancy between urban and rural stations, especially during the summer months.

The main objective of this study is to determine the amount of influence urban heat islands exert on the observed temperature trends across the nation. Several stations are examined in depth, comparing those that are primarily rural with those that are closer to growing population centers. Since the period of record at most stations does not begin until the mid 1900s, 1950 was chosen as the beginning year of this study, continuing through the end of 2005. This time frame ensures that the location of an individual site remains relatively constant; thus minimizing site location changes that can bias temperature data.

The consistent poleward expansion of the Hadley circulation in simulations of 21st century climate

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A consistent poleward expansion of the subtropical arid area is diagnosed in coupled model simulations of the 21st century climate taken from the A2 scenario of the IPCC AR4 project. The simulations show that the shift in precipiation patterns is in concert with a robust expansion and weakening of the Hadley cell. In our work we try to shed some light on the reasons behind those changes.

The predicted reduction in the strength of the Hadley cell is in good agreement with recent theoretical work: A slow-down of the circulation is required to compensate for the under-proportionate intensification of the hydrological cycle in a warmer climate. The predicted expansion of the Hadley cell, on the other hand, is likely to be of extratropical origin: Our analysis suggests that it is attributable to chnages in extratropical tropopause heights.

Decadal variations of temperature and oxygen in the northern East/Japan SeaHong Sik

Min, Cheol-Ho Kim and Sang-Wook Yeh

Long-term variations of temperature and oxygen at intermediate depth in the northern East/Japan Sea are investigated by analyzing the historical data. Vertical profiles of temperature and oxygen are highly influenced by the existence of vertically homogeneous layer such as “mode water”. The decrease of temperature at upper layer coincides with the increase of oxygen at lower layer, which implies that the newly formed water was supplied into the intermediate depth. Temporal variations of both temperature and oxygen suggest that the large volume of the intermediate water such as the Upper Portion of the East/Japan Sea Proper Water and/or the Central Water was supplied in the late 1960’s and the mid-1980’s. It is found that both of air temperature at Vladivostok and sea surface temperature (SST) during winter were relatively cold in the 1960’s and the mid-1980’s in the northern East/Japan Sea where the water mass is believed to be formed. More detail, the overall tendency of the temporal variation of SST rather than air temperature agrees well with those of temperature and oxygen.

Comparison of 57-Year California Reanalysis Downscaling at 10km (CaRD10) with North American Regional Reanalysis

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The NCEP/NCAR Reanalysis for the period 1948 - 2005 was dynamically downscaled to hourly, 10km resolution over California using the Regional Spectral Model. The CaRD10 was compared with the North American Regional Reanalysis (NARR) which is a data assimilation regional analysis at 32km resolution and 3hourly output with the Eta model for the period 1979-present using the NCEP/DOE Reanalysis as lateral boundary conditions. The large-scale component of atmospheric analysis is practically the same in CaRD10 and NARR. The CaRD10 near surface temperature and winds on monthly and hourly scales are similar to NARR with more regional details available in CaRD10. The Southwestern monsoon is poorly reproduced in CaRD10 due to the position of the lateral boundary. The spatial pattern of the two precipitation analyses is similar but CaRD10 shows smaller scale features despite a positive bias. The trend of 500-hPa height is similar in the two analyses but the near surface temperature trend does not agree, suggesting the importance of regional topography, model physics, and land surface schemes. In both analyses precipitation shows a positive trend in areas with large precipitation and a decreasing trend on the leeward side of the Sierras. Several synoptic examples such as the Catalina Eddy, Coastally Trapped Wind Reversal, and Santa Ana winds are better produced in CaRD10 than NARR, suggesting the horizontal resolution of the model has a large influence on these small-scale events. A comparison of a major storm event shows that both analyses suffer from large budget residual. CaRD10's large precipitation is related to wind direction, spatial distribution of precipitable water, and a large moisture convergence. As far as the two regional reanalyses are concerned, uncertainties are large. Overall, CaRD10 shows a very good agreement with the NARR and benefits from higher spatial resolution and fine-scale topography. Dynamical downscaling forced by a global analysis is a computationally economical approach to regional scale long-term climate analysis and can provide a high quality climate analysis comparable to data assimilated regional reanalysis.

Water and Energy Budgets of California from High-resolution Hourly Downscaled Reanalysis

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The water and energy budgets of the atmosphere over California and the surrounding area are estimated using 57-year of California Reanalysis Downscaling at 10km (CaRD10) product. Dynamical downscaling technique used in CaRD10 provides dynamically, thermodynamically, and hydrologically consistent analysis of atmospheric and land variables. Particular emphasis is placed on resolving sub-daily atmospheric water and energy fluxes using CaRD10's hourly output. Winds, energy quantities, and energy fluxes are partitioned into mean and transient eddy fluxes. The estimated water and energy budgets are evaluated with observational data such as radiosonde profiles, hourly precipitation, streamflow, and satellite-derived radiation fluxes. We discuss a possible closure of water and energy budgets by applying an adjustment scheme to a combination of these independently obtained datasets.

Budget study of near surface temperature over California based on California Reanalysis Downscaling at 10km

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Using recently completed 57-year California Reanalysis Downscaling at 10km (CaRD10) (Kanamitsu and Kanamaru, 2006; Kanamaru and Kanamitsu, 2006), budget study of the trend in the near surface temperature is performed. The trend during winter agreed well with trend computed from surface station observations, while that in summer did not agree. The trends in temperature and humidity in the free atmosphere and trends in radiation fluxes, latent heat flux, sensible heat flux, ground flux, cloudiness, soil moisture and precipitation are computed and their consistency with near surface temperature trend is examined. One of the causes of disagreement between CaRD10 trend and observation can be attributed to the missing physical processes in the model used in CaRD10, such as the effect of land use, urbanization, CO2 and aerosol. A limited number of model integration experiments are performed to estimate the contribution of each of these processes to the trend in near surface temperature.

An Experimental Drought Early Warning System based on Regional Reanalysis and Dynamical Forecasts from the Global Forecast System

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Abstract

To develop and implement an experimental Drought Early Warning System (DEWS), NOAA's Climate Prediction Center (CPC) is (i) monitoring the components of the hydrological cycle over North America based on drought indices and RCDAS (Regional Climate Data Assimilation System) diagnostics; (ii) assessing the capability of forecasting drought conditions in the NCEP's current Global Forecast System (GFS); and (iii) examining the physical mechanisms related to drought for better monitoring and prediction. This mission is an integrated component of national policy to monitor and predict drought in support of the NIDIS (National Integrated Drought Information System).

Drought monitoring include the Standardized Precipitation Index (SPI) from observations, modified Palmer Drought Severity Index (PDSI) from the RCDAS, RCDAS diagnostics for more than 30 drought-related variables on weekly, monthly and seasonal time scales, and the ensemble NLDAS (North American Land Data Assimilation System) products. GFS ensemble week1 (1-7 days) and week2 (8-14 days) forecasts of atmospheric and hydrological conditions will also be examined to see their utility in drought forecasting.

Analysis of momentum budget of zonal mean flow by using isentropic representation of EP-flux

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At extratropic circulation, momentum transport by transient and/or stationary eddies contribute to formation of mean flow. Eliassen-Palm flux(EP-flux) is a useful tool to diagnose the wave-mean flow interaction. Monitoring tools of EP-flux and budget of zonal mean momentum equation is developed to analyze changes of zonal flow. In this tools, EP-flux is derived from primitive equations on isentropic surface, with no assumption such as quasi-geostrophic balance. It represents momentum transport by eddies appropriately. Hybrid level data of Japanese 25-year ReAnalysis(JRA-25) whose resolution is T106L40 is used to reduce truncation errors due to vertical differentiation. This tools show momentum balance more accurately than conventional definition of EP-flux. Zonal mean momentum equation for zonal flow is dominated by two terms, Coriolis torque and eddy forcing (convergence of EP-flux). When a location of a jet becomes anomalous, magnitude and sign of the two terms change from its normal. And eddy forcing often plays a important role of breaking or reinforcement of the jet. One of the examples of the analysis is a stratospheric sudden warming event in January 2006. In the event, convergence of EP-flux broke polar night jet from upper to lower stratosphere. Another example, in the troposphere in April 2006, transient eddies were very active over the North Pacific and eddy forcing reinforced the zonal flow around 50-60N.

Statistical Characterization of the Spatiotemporal Variability of Soil Moisture and Vegetation in North America for Regional Climate Model Applications

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Abstract

Previous work has established that the dominant modes of Pacific SSTs influence the summer climate of North America through large-scale forcing,and this effect is most pronounced during the early part of the season. It is hypothesized, then, that the land surface influences may become more dominant in the latter part of the season as remote teleconnections influences diminish. As a first step toward investigation of this hypothesis in a regional climate model (RCM) framework, the statistically significant spatiotemporal patterns in North American precipitation (specified by the standardized precipitation index, or SPI), soil moisture, and vegetation are determined. To specify these respective data we use: CPC gauge-derived precipitation (1950-2002), Variable Infiltration Capacity (VIC) NLDAS soil moisture (1950-2000), and satellite-derived (GIMMS) NDVI (1981-2002). The principal statistical tool used is multiple taper frequency domain, singular value decomposition (MTM-SVD), and this is supplemented by wavelet analysis for specific areas of interest. The significant interannual variability in all of these data occur at a timescale of about 7-9 years and appears to be the integrated effect of remote SST forcing from the Pacific. Considering the entire year, the spatial pattern of precipitation resembles the typical winter ENSO signature. If the summer season is considered separately, the out of phase relationship between precipitation in the core monsoon region and central U.S. is apparent. The largest soil moisture anomalies occur in the central U.S., since precipitaiton in this region has a consistent relationship to Pacific SSTs for the entire year. This helps to explain the approximately 20 year periodicity of drought conditions there. Unlike soil moisture, the largest anomalies in vegetation occur in the southeast U.S. and appear less related to rainfall. In the core monsoon region, interannual variation in vegetation growth is governed by monsoon precipitation. Future RCM work will use these patterns of long-term variability of soil moisture and vegetation in sensitivity experiments investigating land-surface interactions in the warm season.

Drought and Persistent wet Spells over the United States and Mexico

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The wet and dry extreme events as measured by the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI) have preferred regions to occur and persist. The interior United States west of 90-95 ^{o}W and the northwestern Mexico are more prone to droughts and persistent wet spells. On contrary, the extreme events are less persistent over the eastern United States and California. The physical mechanisms for the regional preference are examined by classifying extreme events into three categories: Multi-decadal, interannual and intraseasonal time scales.

The extreme events which have decadal time scales are located over the northwestern Mexico and the western Mountain regions. Rainfall over these two regions is associated with multi-decadal modes of SSTAs.

The extreme events which have interannual time scales are located over the Great Plains and the Southwest. The SST forcing which persists over the raining season has consistent influence on rainfall over these areas. Over the Southwest there is little rainfall in spring and soil moisture reaches a minimum. Once the monsoon starts, daily rainfall continues for one to two months. Rainfall is influenced largely by the large scale atmospheric conditions with little local modulation from soil conditions. Over the Great Plains, the coupling between soil moisture is strong and is not limited to the local feedbacks. Over the southern Plains, soil moisture anomalies over Texas in spring are associated with summer rainfall anomalies over the Great Plains. The location and pattern of soil moisture anomalies in spring influence the precipitation pattern.

The extreme events are less likely to occur and persist over the central eastern United States, the East Coast and the Ohio Valley. These areas have very weak seasonal cycle. Rainfall from many seasons can contribute to the SPI or the PDSI. Rainfall is influenced by ENSO events which often last from winter to summer. However, ENSO often has the opposite impact on winter and summer rainfall over the same region.

Land surface processes depicted by the North American Regional Reanalysis and the Noah Land Data Assimilation

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The land surface processes in the NCEP North American Regional Reanalysis (NARR) and the Noah Land Data Assimilation System version 1 (NLDAS1) and version 2 (NLDAS2) are compared in terms of climatology, anomalies and variability.

There are large uncertainties in soil properties and land surface variables revealed by the data assimilation systems. The products depend on the model and data inputs. The regional reanalysis (RR) has an old version of the Noah model and coarse resolution of 32 km. The advantage is that it has the atmospheric component so we are able to examine the atmospheric circulations related to land surface properties. Both the NLDAS versions have finer resolution of 12 km. They are forced by the observed precipitation.

This study examines the hydrologic cycle depicted by the RR, and NLDAS1 and NLDAS2. They will be compared with limited observations. In addition to the comparison of climatology and anomalies, our focus will be on the relationships among precipitation, evaporation (E) and soil moisture. If the relationships among hydrological variables are similar from all three products, then these products can be used to study physical mechanisms and feedback processes between soil moisture and precipitation.

Observed and Simulated Soil Moisture Variability Responds to Land Surface Hydrological Processes

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The exchange of soil moisture and heat between the land surface and the overlying atmosphere is very important for weather and climate prediction. Since soil moisture is one of the controls of the land surface energy and water budgets, and thus impacts the strength of land-atmosphere coupling, understanding and accurately representing spatial and temporal variability of soil moisture is crucially important.

Several soil moisture data sets, such as the observed Illinois soil moisture data set, three retrospective offline run datasets from the Noah land surface model (LSM), VIC LSM and CPC leaky bucket soil model, and three reanalysis datasets (North American Regional Reanalysis, NCEP/DOE Global Reanalysis and ECMWF ERA40), are used to study the spatial and temporal variability of soil moisture and its response to the major components of land surface hydrologic cycles: precipitation, evaporation and runoff. Detailed analysis was performed on the evolution of observed 2m soil moisture vertical profile. Some interesting inter-comparisons are conducted and existing problems are discussed. Over Illinois we compare to observations, but for the US as a whole some impressions can be gained by comparing the multiple soil moisture-precipitation-evaporation-runoff data sets to each other. The purpose of this study is to quantify the role of dominant land surface hydrological processes and investigate the reasons of soil moisture variability on the different spatial-temporal scales, such as where do the low frequency variations in soil moisture come from? What are the magnitudes and partitions of major land surface water balance component (Precipitation, Evaporation and Runoff) variations on seasonal to inter-annual time scales?

Land Surface Hydrological Extremes and Their Relation to Precipitation, Land and Ocean Temperature Extremes

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ABSTRACT

A weather or hydrological extreme is an event that departs significantly from its normal state. Extreme weather and hydrological events can have serious impacts on the human society and ecological systems. Understanding and eventually predicting these extreme events will have great benefit.

In this study, the observed monthly CPC global land surface precipitation, the CPC global land surface air temperature and the NCDC global sea surface temperature data sets were used to identify the most dominant extreme signals (e.g. droughts, floods, cold surges and heat waves) and their magnitudes, temporal-spatial distributions over the globe for period of 1948 to present. Then, several simulated land surface data sets, such as the NCEP-DOE Global Reanalysis, the ECMWF ERA40, the North American Regional Reanalysis, the CPC Leaky Bucket Hydrological Model and two NLDAS (Noah and VIC Land Surface Models) 50+ year offline runs, were used to identify the hydrological extremes and, more in general, large inter-annual variability over the globe and the US. This work will focus on following questions: whether or not and how the frequency and magnitude of the extreme events has changed over the last 5 decades? How about changes in the spatial distribution of extremes? How do the hydrological extremes respond to the observed precipitation and temperature extremes? What are the capability and uncertainty of the current reanalysis systems and other land surface data analysis systems to reproduce these extreme events?

NAMAP2 and the NAME Climate Process Team

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We present initial results from the second phase of NAMAP (called NAMAP2), a model assessment effort associated with the North American Monsoon Experiment. The simulations provide a set of comparable runs for the North American warm season of 2004, during which NAME enhanced monitoring took place in the field. This project is a follow-on to the pre-field phase set of simulations known as NAMAP (Gutzler et al. 2005), which established benchmarks for model improvement based on common simulation of an earlier year (1990). Results from NAMAP2 will feed into operational model development at NCEP via the NAME Climate Process Team. NAMAP2 simulations were completed early this year; results and assessment are ongoing.

The Double-ICTZ Problem in IPCC AR4 Coupled GCMs: Ocean-Atmosphere Feedback Analysis

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This study examines the double-ITCZ problem in the coupled general circulation models (CGCMs) participating in the Inter-governmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). The 20th century climate simulations of 22 IPCC AR4 CGCMs are analyzed, together with the available AMIP runs from 12 of the models. To understand the physical mechanisms for the double-ITCZ problem, the main ocean-atmosphere feedbacks, including the SST gradient-trade wind feedback (or Bjerknes feedback), the SST-surface radiative flux (SRF) feedback, and the SST-surface latent heat flux (LHF) feedback, are examined in detail.

The results show that most of the current state-of-the-art CGCMs has some degree of the double-ITCZ problem, with about half of the models displaying prominent double-ITCZ pattern, which is characterized by cold SST bias both on the equator and off the equator, insufficient precipitation on the equator, but excessive precipitation off the equator. These are usually associated with overly strong trade winds, insufficient SRF, and excessive LHF.

The AMIP runs do not show significant double-ITCZ problem, suggesting that the problem comes from ocean-atmosphere feedback. Feedback analysis demonstrates that the double-ITCZ problem in different models is associated with different biases in ocean-atmosphere feedback. In some of the models it is associated with overly strong Bjerknes feedback, which in turn is caused by (1) excessive precipitation especially over medium SST, and (2) too weak mechanical damping in the boundary layer. In other models it is associated with incorrect sign of SST-LHF feedback, which in turn is caused by overly enhanced surface air humidity at higher SST. The possible methods for alleviating these systematic biases are discussed.

Reference:

Lin, J. L., 2006: The double-ITCZ problem in IPCC AR4 coupled GCMs: Ocean-atmosphere feedback analysis. *J. Climate*, submitted.

The sensitivity of simulated intraseasonal variability in Tropics to change in resolution and physical parameterization scheme

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This study examines the effect of change in horizontal resolution and physical parameterization scheme of atmospheric global model on the simulated intraseasonal variability over the equatorial western Pacific region. The model utilized in this study is based on a new global model which is developed by the Yonsei University under the project for the development of a new KMA global forecast system (YOnsei University Research model System, YOURS). The starting point of the new model system is routed in the NCEP global forecast system (GFS) as of 2000 (Kanamitsu et al. 2002), but with major differences in dynamics and physics.

However, the original model (NCEP GFS) framework in this study is employed to prepare references for investigating the characteristics of newly developed global model. Several experiments are designed to investigate the sensitivities of horizontal resolution and physical schemes to simulate intraseasonal variability. First, the control experiment employs T62L28 resolution and the same physics with the NCEP GFS model as of 2000. For investigation of resolution dependence, two more experiments are performed with T126L28 and T248L28 resolutions. As well, some experiments are designed to examine the effect of different physical parameterization methods in deep convection and PBL processes on simulated intraseasonal variability.

The simulations are conducted for the boreal summer in selected years. For each experiment, 5-member ensemble runs are performed using observed sea surface temperature, sea-ice and snow data during the simulation period. More detailed results will be discussed later.

Investigation of the Summer Climate of North America: A Study with the Regional Atmospheric Modeling System

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53 years of the NCEP-NCAR Reanalysis (1950-2002) are downscaled with the egional Atmospheric Modeling System (RAMS) to generate a regional climate model (RCM) climatology of the contiguous U.S. and Mexico. The simulations capture the climatological transitions in precipitation and temperature associated with the North American monsoon, though model generated precipitation is overestimated. The time varying modes of convection are well represented, particularly the diurnal cycle. Interannual variability in the simulations is evaluated with respect to the dominant modes of Pacific SST variability. Time-evolving teleconnections accelerate or delay monsoon evolution. The most significant response in RAMS-generated fields occurs simultaneously with the time of maximum teleconnectivity in July. At this time, there is an opposite relationship between precipitation in the core monsoon region and the central U.S. The teleconnections affect low-level moisture transport and the time-varying modes of convection. Recent tropical SST warming is associated with a general increase in rainfall over most of North America, except in western Mexico. The long term trend in Mexican monsoon rainfall is due to a decrease in moisture transport from the eastern Pacific.

Interpretation of NOAA/NCEP and ECMWF week 1 and week2 products during the 2006 summer AMMA Special Observing Period : implications for the monitoring and forecasting of the late onset and breaks of the West African monsoon

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Summer 2006 over west Africa coincided with the Special Observing Period (SOP) of the AMMA project. An AMMA operational forecasting center was set up at the African Centre for Meteorological Application to Development based in Niamey Niger. A late onset with significantly below normal rainfall in June 2006 were features of strong concern for the observing campaign and the agriculture sector in the Sahelian region of West Africa. Research aircrafts could not make measurements related to strong MCSs and squall lines before mid July 2006. The agriculture sector suffer from the late onset and associated disturbances on the planting dates.

This paper shows how NCEP and ECMWF week1 and week2 products contributed to the monitoring and forecasting of the late onset and June below normal rainfall that prevailed in summer 2006. Seasonal and weekly outlooks are also used as guidance for a more reliable day to day weather forecasting. Suggestions to transfer this experience into operations and integrate forecasts from daily to seasonal timescales in the framework of WMO Coordinated Observation and Prediction of the Earth System (COPES) initiative is discussed.

Overview of the 2006 Global Monsoons

CPC Monsoon Working Group
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This study will present an overview of the 2006 Global Monsoon. It will focus on the onset, demise and character of the global Monsoons in 2006, and compare the 2006 monsoons with the monsoons of previous years. Also we will summarize some of the 2006 monsoon impacts.

Relationship between African Easterly Wave and Hurricane over the Atlantic and the America

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In this study we examine the relationship between the African Easterly Wave (AEW) and Hurricane development over the Atlantic and the Americas. Our results are based on ERA40 reanalysis data and simulations with the NASA Seasonal-to-Interannual Prediction Project (NSIPP-1) atmospheric general circulation model (AGCM). We will present results from both the analysis and model simulations showing the relationship between AEW and the hurricane development over the Atlantic, and discussion the interannual variability of Hurricane development in terms of AEW, MJO, and ENSO.

Monitoring Convective Systems Over the Zone of West African Monsoon

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Abstract

During the rainy season, storms of different intensities occur over the Central and West African region and most of the time they were accompanied by thunder and lightening of relatively large magnitude as was observed over Niamey. Three major kinds of storm formations were experienced during the period between July and September 2005.

The first kind was a well-developed squall line resulting from the monsoon wind flow systems. This kind usually start as a well organised squall lines from vortices located over East Africa and propagates westward moving across cities in central and west Africa before decaying or reinvigorating as the case may be and proceeding to the Atlantic Ocean. These type of storms are usually more organised and tend to be fuelled by the presence of strong African Easterly Jets (AEJ) which are usually prominent at the mid level altitudes, i.e. 600hPa and 700hPa. The second kind of storms that were observed during the period, were those developed as a result of in-situ convective cloud development activities resulting from the presence of favourable instability conditions. The third kind were those that are actually generated as a result of Orgraphic effects which are informed by the presence of Mountains and high grounds over the continent obstructing the flow of monsoon wind and leading to convective cloud development.

In this work, we looked at the best methods of making reliable, timely and accurate weather forecasts for such convective cloud developments and understanding the most favourable tracks that these storms followed during their westwards propagation into the Atlantic Ocean. The results from this work are being closely linked to the fact that most of the weather and climate-related disasters especially the occurrence of Hurricanes and Tropical Cyclones over the Southern coast of USA developed from some of these storms having their origins from either West or East Africa.

Interannual variability of tropical storm counts in the eastern Pacific Ocean

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Interannual fluctuations of the number of tropical storms affecting the west coast of North America are shown to be modulated by the ENSO cycle and by Pacific decadal variability. More tropical storms affect the Pacific coast during La Niña years, when equatorial Pacific Ocean temperature is anomalously cold, compared to El Niño years. The difference in near coastal storm counts between La Niña and El Niño years was particularly pronounced during the mid-20th Century epoch when cold equatorial temperatures were enhanced, as described by a standard index of the Pacific Decadal Oscillation. Composite maps of the large scale circulation during warm seasons with high and low landfall counts show that the anomalies associated with the "cold" phase of ENSO and PDO are consistent with tropical storm tracks preferentially steered toward the west coast.

The relationship between the North Atlantic and the Eastern North Pacific Hurricane season activities and the associated circulation changes

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Abstract:

The relationship in the levels of hurricane activity between the North Atlantic and Eastern North Pacific Ocean basins will be examined on interannual as well as interdecadal time scales. Composite aspects of regional and global scale circulation features such as vertical wind shear, geopotential heights, surface pressure, and sea surface temperature associated with active, inactive and neutral phases of hurricane activity in both ocean basins will also be presented using NCEP/NCAR reanalysis data. While reliable observed measures of hurricane activity including the strengths of tropical storms and hurricanes and the associated sustained wind speeds (taken every 6 hours) are available for the North Atlantic basin for as long as the period of reanalysis data, it is rather limited for the Eastern North Pacific basin, thus making any low frequency analysis relatively difficult.

Compared with the North Atlantic basin, the East Pacific is a much smaller region and is the most prolific generator of tropical storms and hurricanes. At least it used to be. Lately, there is a marked decrease in the East Pacific hurricane activity and at first glance it may appear to be related to the increase in hurricane activity in the North Atlantic since 1995. However, the decrease in East Pacific activity seems to have started earlier than 1995. These and other aspects of the changing nature of the relationship between the hurricane activities of the two ocean basins will be examined and presented.

Characteristics of Seasonal Storminess for Alaska

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Impacts from storms in the Alaska domain have received increasing attention as low-level winds, precipitation, and wave action seem to be having an increasing impact along the coastlines of Alaska. This is apart from the fact that it is unclear whether or not storm frequency and/or intensity are changing. The socioeconomic impacts of these issues are far reaching and an understanding of the conditions that occur prior and during seasons of above and below normal storminess is important. The paper illustrates characteristics of the atmosphere and ocean for above and below normal seasonal storminess for Alaska. A cyclone activity index is used to identify where individual seasons rank in the historical record. In addition, an Alaska storm track web page has been developed to monitor and assess storm track variability and can be used to relate changes in storminess to some of the leading modes of climate variability (ENSO, MJO, AO, etc.).

Objective Identification of Atmospheric Regimes despite nearly Gaussian Statistics

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In this study we utilize Hidden Markov Models (HMM) for atmospheric regime identification. HMMs are widely used in areas like speech recognition and molecular dynamics. A Hidden Markov Model is designed to describe the situation in which part of the information of the system is unknown or hidden and another part is observed. Thus, a HMM is a stochastic process with hidden and observed states. The hidden process consists of a sequence X(1), X(2), X(3), ... of random variables taking values in the state space, the value of $ X_t $ being the state of the system at time t. In practice these states are not observable and, therefore, are called hidden. In this study we shall identify the X(i) with atmospheric flow regimes. The hidden states X(i) are assumed to evolve according to a Markov model. In a HMM each hidden state causes a specific output O(t). This output is drawn from a random distribution (Gaussian) and this distribution is conditioned on the hidden state X(t). HMMs are a powerful tool to systematically identify metastable regions in phase space. We shall identify these metastable regions with atmospheric regimes.

To identify atmospheric regimes we analyze the estimated HMM transition matrix for metastable states. Metastable states are those hidden states that persist for a long time relative to the remaining hidden states. These metastable stable states are identified by estimating the eigenvalues of the Markov chain transition matrix. Since this transition matrix is a stochastic matrix its first eigenvalue is always 1 and corresponds to the invariant measure. The absolute value of all other eigenvalues is less then 1. If the eigenvalue spectrum of the transition matrix contains a gap then we shall identify the corresponding hidden states with eigenvalues close to 1 as atmospheric regimes. A gap in the eigenspectrum indicates a time scale separation.

In a recent publication we applied the HMM procedure to a 57 mode model of barotropic flow over topography with a large scale mean flow. The large scale mean flow is the variable with the longest correlation time and is utilized for the HMM analysis. In the case of high topography we identified atmospheric flow regimes which correspond to zonal and blocked flow. By decreasing the height of the topography the metastable behavior gradually vanishes, indicating that the interaction between the topography and Rossby waves create the regime behavior. The HMM algorithm will also be applied to a 3 layer quasi-geostrophic model with realistic climatology and a comprehensive GCM to investigate their regime structures. The prospects of long-range forecasts by utilizing these atmospheric regimes will be discussed.

Adaptive Stochastic Modeling using Data Assimilation

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and

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One persistent problem with ensemble weather forecasts is that the spread of the forecasts is generally much smaller than the root mean square prediction error. Some forecast centers have implemented stochastic parameterizations in order to increase the forecast spread, but without any real guidance from data. This work demonstrates that data assimilation can be used to provide parameter distributions for use by stochastic parameterization schemes. It is shown that when the system of interest is stochastic the expected variability of a stochastic parameter is somewhat overestimated when a deterministic model is employed for parameter estimation. However, this overestimation is ameliorated through application of the dynamical Central Limit Theorem, and good estimates of both the first and second moments of the stochastic parameter can be obtained. It is also shown that the overestimated variability information can be utilized to construct a hybrid stochastic/deterministic integration scheme that is able to accurately approximate the evolution of the true stochastic system. That is, data assimilation can properly exploit observed data properties to eliminate the need to rewrite a numerical forecast model with computationally expensive stochastic integration schemes.

The techniques described in this work may be particularly valuable in accounting for the effects of unresolved time and space scales in numerical climate models, which generally must be run with lower spatial and temporal resolution than numerical weather prediction models.

Global spatial organization of temperature extremes

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The recent heat waves in the Northern Hemisphere and large ice shelf collapses over the Artic and Antarctic have been linked to global warming and rapid temperature increase over the last decades. To recognize the anthropogenic nature of the recent warming, it is necessary to understand the elements responsible for the natural variability of the climate system. In this study, we examine global daily detrended temperature anomalies in the present climate (1948-2005) using NCEP/NCAR reanalysis and over the past 300 yrs (1750-1975) using reconstructed temperature over Northern Europe and New Zealand during summer. This analysis is based on temperature variability interpreted within the framework of random walks. We show evidence of global spatial organization of extreme temperature regimes and the existence of an inter-hemispheric seesaw. This seesaw is characterized by coherent regimes of extreme temperature anomalies over extensive portions of the Northern Hemisphere, tropical South America, tropical Africa and Antarctica with opposite signs over the Southern Hemisphere oceans, western and southern South America. Paleoclimatic summer records in Northern Europe and New Zealand indicate that inter-hemispherical teleconnections in extreme anomaly regimes have occurred in the last 300 yrs and exhibit interdecadal variations. The last decade (1990-2000) was characterized by enhanced positive anomalies over the Southern Oceans. There is indication that the regime of extreme anomalies after 2000 has switched back to the mode characterized by positive anomalies over the Northern Hemisphere and the tropical regions of the Southern Hemisphere and Antarctica, and negative anomalies over the Southern Oceans and subtropics of the Southern Hemisphere.

Climatology of Santa Ana winds in Southern California

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The occurrence and variability of Santa Ana wind (SAW) events in southern California are investigated with the North American Regional Reanalysis (NARR) and station data for the period 1979-2005. The high spatial resolution (32 km) and consistently derived NARR data provide an important tool to characterize Santa Ana winds in southern California including their diurnal variability. The poster will present statistics characterizing the seasonality, interannual variability and diurnal cycle of SAW. The vertical structure of strong SAW events derived from NARR data will also be presented. Finally, the work will discuss indexes that can be used in real time to monitor SAW events.

Poster Session 3 (Thursday, October 25, 2006)

A SEASONAL HYDROLOGIC ENSEMBLE FORECAST SYSTEM OVER THE EASTERN US

Lifeng Luo, Eric F. Wood

"Progress in diagnosing, modeling and predicting seasonal climate variability represents a major scientific advancement of the 20th century, however, progress in the effective utilization of forecasts has lagged behind" (Goddard et al, 2001). This research builds on an experimental seasonal hydrologic forecast system in the Ohio River basins to address a central scientific question of whether seasonal climate predictions have sufficient skill to provide improved hydrologic forecasts and water management information across the eastern U.S., as well as consider how seasonal hydrologic predictions can be made most skillful given the climate predictions, and how this skill can be quantified.

The project focuses over the eastern U.S., and carries out the following two major activities:
1) The development of an expanded Eastern U.S. hydrologic ensemble forecast system that will include all basins east of the Mississippi main stem up to the mouth of the Ohio River.
2) An evaluation and analysis of the resulting seasonal hydrological predictions, with a focus on understanding the reliability of the ensemble forecasts and the overall uncertainty in the hydrologic ensembles due to model (seasonal climate and hydrologic) uncertainty, calibration uncertainty, data uncertainty, and so forth.

The project will enhance NOAA operational activities by extending current links to the NCEP-lead LDAS activities, by providing results useful for the NWS/HDL proposed water initiative and by demonstrating the usefulness of the seasonal hydrologic forecasts through application studies.

Update on West Wide Hydrologic Forecasting at the University of Washington

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We describe recent updates to the UW westwide seasonal hydrologic forecasting system. The system consists of the application of the Variable Infiltration Capacity (VIC) macroscale land surface model over the western U.S. at 1/8 degree spatial resolution for ensemble-based seasonal hydrologic prediction at lead times of up to one year. Climate forecast ensembles are downscaled from climate models such as the NCEP Coupled Forecast System (CFS), or taken from the CPC official seasonal outlooks, or based on the well-known Extended Streamflow Prediction (ESP) method, and the ESP ensembles are further conditioned on ENSO and PDO state. The primary forecast products are: 1) monthly streamflow distributions and volume runoff statistics for major locations in the western US; 2) diagnostics of related climate and water balance variables (soil moisture and snow water equivalent or SWE) during the water year up to the forecast date; and 3) west-wide spatial maps of monthly forecast ensemble averages for runoff, soil moisture and SWE. This poster reports recent results from the use of this system as a testbed to evaluate: a) improvement of the forecast's initial SWE conditions via data assimilation of in situ snowpack observations; b) expansion of the forecasting domain east of the Continental Divide, e.g., to the Missouri R. Basin; and c) ensemble forecasts formed from a Bayesian combination of predictions from a suite of land surface models consisting of VIC, the NWS grid-based Sacramento model and the NCEP Noah model.

The potential for global flood and drought prediction

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While the weather and climate forecast methods have advanced greatly over the last two decades, this capability has yet to be evidenced in mitigation of water-related natural hazards (primarily floods and droughts), especially in the developing world. For instance, Mozambique experienced major droughts in 2005 and 2002 which resulted in widespread food shortages and major floods in 2000 and 2001 which affected large parts of the country. In Southeast Asia, early monsoon rains that began in July 2000 resulted in flooding of the Mekong River and its tributaries in Cambodia, Vietnam, Laos and Thailand. It was the worst flooding in several decades and affected more than 4.5 million people and killed several hundreds. Mitigation of these events through advance warning was at best modest; despite the above noted improvement in weather and climate forecasts, there is at present no system for forecasting of floods and droughts globally, notwithstanding that the potential clearly exists. We describe a methodology that is eventually intended to generate global flood and drought predictions routinely. It draws heavily from the experimental North American Land Data Assimilation System (NLDAS) and the companion Global Land Data Assimilation System (GLDAS) for development of nowcasts, and the University of Washington Experimental Hydrologic Prediction System to develop ensemble hydrologic forecasts based on the NCEP Global Forecast System for lead times from seven days to six months using the University of Washington/Princeton University Variable Infiltration Capacity (VIC) macroscale hydrology model. In the prototype (tested using retrospective data), VIC is driven globally up to the time of forecast with daily ERA40 precipitation (rescaled on a monthly basis to a station-based global climatology), ERA40 wind, and ERA40 average surface air temperature (with temperature ranges adjusted to a station-based climatology). In the retrospective forecasting mode, VIC is driven by global NCEP ensemble 15-day reforecasts provided by Tom Hamill (NOAA/ERL), bias corrected with respect to the adjusted ERA40 data and further downscaled spatially using higher spatial resolution Global Precipitation Climatology Project (GPCP) 1dd daily precipitation. Downward solar and longwave radiation, surface relative humidity, and other model forcings are derived from relationships with the daily temperature range during both the retrospective (spinup) and forecast period. The initial system is implemented globally at one-half degree spatial resolution. We evaluate model performance retrospectively for predictions of major floods for the Oder in 1997, the Mekong in 2000 and the Limpopo in 2001.

Increase in Near Surface Temperature Simulation Skill due to Predictive Soil Moisture in a Numerical Seasonal Simulation

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Two sets of 12-year 8-member ensemble integrations were run with the ECPC SFM to investigate the sensitivity of near surface temperature skill to evolving soil moisture. The first ensemble had evolving soil moisture, which was fully interactive with the atmospheric component of the model. The second ensemble had soil moisture fixed to the monthly climatological value. Several regions showed an increase in skill in the evolving soil moisture ensemble. These areas include Northeastern Australia in January and February, Southeastern Africa in May and June, Western Australia in July and August, Northwestern Russia in July and August, and Indo-China in September and October. Most of these regions either had a high soil moisture time-lag correlation (soil moisture memory) or high year-to-year soil moisture variability.

The sensitivity to soil moisture is considered both in terms of actual predictability (anomaly correlation with observations) and theoretical potential predictability. In several cases there were discrepancies between the results from anomaly correlation and potential predictability. It was found that when comparing two sets of integrations, improvements in potential predictability do not necessarily give a reasonable estimate to improvements in anomaly correlation.

Launching Phase II of NLDAS: Adding a Seasonal Prediction Component and 25-year Land Reanalysis

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The North American Land Data Assimilation System (NLDAS) is a multi-institutional and multi-model research project in an uncoupled land-only mode. To date, the NLDAS executes the four land models of Noah, VIC, Mosaic, and SAC. The NLDAS has two over-arching broad purposes. The first, which was the main focus of Phase I of NLDAS, is to provide analysis and reanalysis of land states (such as soil moisture and temperature, snowpack, vegetation state, and streamflow) and their associated land surface water and energy budgets. The realtime land analyses, together with their retrospective reanalysis counterparts, can be used for monitoring (such as drought and flood monitoring, or agricultural management) or for providing initial conditions for the land component of coupled regional weather and climate prediction models. The second and newer purpose is uncoupled ensemble prediction of land states by forcing the NLDAS land models with ensemble predictions of land surface forcing over forecast ranges from weeks to months.

Phase I of NLDAS, which spanned the GCIP and GAPP programs preceding CPPA, focused mainly on the analysis mode, with some pilot work done on the prediction mode. The focus of this presentation and Phase II of NLDAS is the prediction mode, with emphasis on the seasonal range. Phase II was launched recently within the CPPA program via collaborations between NCEP/EMC, NWS/OHD, NASA/GSFC/HSB, NCEP/CPC, Princeton University, University of Washington (UW), University of Maryland, and other research institutions. Phase II will include 1) a long-term 25-30 year NLDAS retrospective analysis of all four land models using CPC precipitation analyses and all other surface forcing from NCEP's North American Regional Analysis (NARR), 2) a daily realtime update using NARR's realtime extension known as the Regional Climate Data Assimilation System (R-CDAS) and 3) a seasonal predictive component. This prediction component will utilize bias-corrected ensemble seasonal predictions of surface forcing from multiple global coupled climate models and empirical ensemble seasonal predictions derived from official CPC seasonal outlooks and the historical record. Bayes theory and other objective tools will be used to weight the different sources of predicted surface forcing.

In this presentation some preliminary results will be presented. For example, as a pilot project for the upcoming 25-30 year NLDAS land reanalysis, an 11-year NLDAS reanalysis has been performed from the land surface forcing produced in Phase I (October 1996 - September 2006). Disregarding the first year as spin-up, we have conducted a 10-year land-surface water and energy balance analysis from the Noah, Mosaic and VIC models (the SAC model will be added soon). The results are employed to analyze temporal and spatial distributions for soil moisture, soil temperature, sensible and latent heat fluxes, streamflow, and skin temperature, which are compared with observations. For the seasonal prediction component, we have thus far ported to NCEP and demonstrated the VIC-based ensemble seasonal streamflow prediction system developed under CPPA-sponsorship at Princeton University for the east half of CONUS using ensemble seasonal forecasts of surface forcing from NCEP's Climate Forecast System (CFS). Presently, we are preparing to port to NCEP the methodology of the CPPA-sponsored development at University of Washington (UW), whereby the official seasonal forecasts of CPC are applied to generate additional ensemble members of seasonal predictions of land surface forcing for driving multiple land models over the west half of CONUS. Within the next year at NCEP, both the dynamical prediction approach of Princeton and the empirical prediction approach of UW will be applied across the entire CONUS domain for all four NLDAS land models (VIC, Noah, Mosaic, and SAC).

Influence of soil moisture and snow on regional climate predictions

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Three long term North American (NA) climate simulations with the Experimental Climate Prediction Center (ECPC) Global to Regional Spectral Model (G-RSM) have now been developed for the period 1979-2004. These NA simulations include: a) control (CTL), b) climatological surface forcing (CLM), and c) precipitation replacement (PR). Snow and soil moisture fields from these three basic climate simulations were then used as initial conditions for longer-range predictions. Every month, 1982-2004, the G-RSM was started three times globally from the National Centers for Environmental Prediction-Department of Energy Reanalysis II (R-2) initial conditions, except over NA, where the three different surface conditions derived from the long term simulations were used instead of the R-2 initial conditions. The RSM simulation fields affected both the global and regional fields over this area. All forecasts are for duration of one month. Additional ensemble members and forecast lead-time for each of the basic experiments are being added as computer resources become available. For the first few weeks, forecasts of surface air temperature (SAT) started from the PR compared best with PR simulation, forecasts started from the CTL simulation compared best with the CTL simulation, etc. However, in comparison to the North American Regional Reanalysis (NARR), the PR initialization provides the best forecast in the central part of the US, especially during the spring and summer.

Impact of Soil Moisture on Precipitation: A Sensitivity Study with the GEOS5 AGCM

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The GLACE experiment is run with the GMAO GEOS5 coupled atmospheric model to evaluate the impact of soil moisture anomalies on precipitation and temperature variations during the Northern Hemisphere summer. The experiment essentially involves comparing the output of two 12-member ensembles: a standard AMIP ensemble with prescribed sea surface temperature (SST) and an ensemble using the same SST but in which each ensemble member is forced with the subsurface soil moisture time series produced by one member of the first ensemble. Initial analysis suggests a coupling strength in GEOS5 that is much weaker than that of the GMAO's earlier NSIPP GCM, though the patterns generated are somewhat similar. The GLACE experiment was then repeated after modifying the values of key parameters of the imposed moist convection physics. These sensitivity studies show how the strength of land-atmosphere coupling can vary with the representation of moist convection.

Revised Prediction of Seasonal Atlantic Basin Hurricane Activity from August

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An updated statistical scheme for forecasting seasonal tropical cyclone activity in the Atlantic basin by 1 August is presented. Approximately 95 percent of all tropical cyclone activity occurs in the Atlantic basin after 1 August. Previous research by Gray and colleagues at Colorado State University showed considerable hindcast skill using a combination of predictors including the stratospheric quasi-biennial oscillation (QBO), West African rainfall, measures of El Niño-Southern Oscillation, and sea level pressure and zonal wind anomalies in the Caribbean.

Prediction of Extratropical Storminess

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This study is concerned with estimating the predictable variations of extratropical daily weather statistics ("stormtracks") associated with global sea surface temperature (SST) changes on interannual scales, and its magnitude relative to the unpredictable noise. The SST-forced stormtrack signal in each northern winter in 1950-2003 is estimated as the mean stormtrack anomaly in an ensemble of atmospheric general circulation model (AGCM) integrations for that winter with prescribed observed SSTs. Since the stormtrack signals cannot be derived directly from those ensembles with archived monthly AGCM output only, they are diagnosed from the SST-forced winter-mean 200 mb height signals using an empirical linear stormtrack model (STM). For four particular winters, the El Nino of JFM 1987, the El Nino of JFM 1998, the La Nina of JFM 1989, and the La Nina of JFM 1999, the stormtrack signals and noise are estimated directly, and more accurately, from additional large ensembles of AGCM integrations. The linear STM is remarkably successful at capturing the AGCM's stormtrack signal in these four winters, and is thus also suitable for estimating the signal in other winters. We find that a predictable SST-forced stormtrack signal exists in many winters, but its strength and pattern can change substantially from winter to winter. The pattern correlation of the SST-forced and observed stormtrack anomalies is high enough in the Pacific-North American sector to be of practical use. In the Euro-Atlantic region, we find much lower correlations, which we argue arise from substantial AGCM error in representing the regional response to tropical SST forcing, rather than intrinsically low predictability. The magnitude of these errors is compared with those computed directly from recent stormtrack forecasts made with coupled ocean-atmosphere GCMs.

Assessing 20th Century Tropical Cyclone Activity in the NSIPP-1 AGCM

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The Seasonal Genesis Parameter (SGP) is a statistical tool that was developed by William Gray to show regions that are favorable for tropical cyclone formation. The SGP's spatial pattern is highly correlated with the climatological distribution of tropical cyclone activity. This tool is applied to century long simulations of the NSIPP-1 AGCM. The climatological value of the model's SGP will be compared to SGP derived from the NCEP-NCAR Reanalysis and ERA-40.

The simulations and reanalyses show that years with high SGP values correspond to a higher than normal number of tropical cyclones. The relative contributions of the six different terms that make up SGP will be evaluated, as well as separating the contributions of these terms on decadal and inter-annual timescales.

Verification of the IRI experimental dynamical seasonal tropical cyclone forecasts

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Since April 2003, the IRI has issued experimental dynamical seasonal tropical cyclone forecasts for five regions of the world: the western North Pacific, North Atlantic, eastern North Pacific, Australian, and South Pacific. These forecasts are based on a two-tier procedure, where various possible scenarios for the sea surface temperatures are forecast first, based on statistical or dynamical models, and then an atmospheric model is forced with those predicted SSTs. Tropical cyclone-like vortices are then identified and tracked in the atmospheric model outputs. The model tropical cyclone seasonal frequency and, in the Northern Hemisphere, ACE (Accumulated Cyclone Energy) are then bias corrected, based on the historical performance of the model forced with observed sea surface temperatures in each region. The probabilities of each tercile category in the forecasts based on the different scenarios and ensemble members are then obtained, and often subjectively modified (usually weakened) by the forecasters, based on their experience and the model performance.

The forecasts are issued for the three or four months of peak tropical cyclone activity (e.g., August to October for the Atlantic), starting 4 months or 3 months prior to the first month of the peak season, and are updated monthly until the first month of the peak season. We show the verification of these forecasts and discuss their skill for the 2003-2006 period as a function of region and lead time, and compare these with the model skill using perfect (observed) SST forcing over the much longer hindcast period of 1950-2002. The viability of this approach to prediction of tropical cyclone activity, and near-term plans, are discussed.

Preliminary Results of High Resolution Dynamical Hurricane Seasonal Simulations

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We present simulations of the 2004 Atlantic hurricane season using the FSU global spectral model run at T126 (1 degree) resolution and observed weekly sea surface temperatures. These experiments are a precursor to future experiments where we plan to use a T126 coupled model with a variable resolution ocean model and the FSU regional spectral model. An analysis of the 2004 simulation shows very realistic tropical storm activity. The generated hurricane-like vortices compare well with their real-world counterparts, with warm cores, strong cyclonic inflow at lower levels and anticyclonic outflow above 200 hPa, heavy precipitation and evaporation and deep central pressures. Genesis occurs in climatically favored regions. Approximately 20 storms were generated, compared to 15 observed. Of those, 7 were landfalling storms, compared to 9 observed. Storm tracks were very realistic when compared to climatology, and some storms can be tracked for more than 10 days. The seasonality of storm genesis was reasonable, though not quite as sharply peaked in late August/early September as observed.

The next step is to look at interannual variability. We running ensembles for the past 20 years and hope to have those results in the near future.

Ensemble forecasts starting from coupled bred vectors with NASA coupled general circulation model

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A coupled breeding cycle has been implemented in NASA coupled general circulation model. Bred vectors rescaled with different norms are used to initialize the ensemble forecasts for El Niño prediction. During a 10-year period (1993-2002), our results show that forecast experiments initialized from bred vectors showed a large improvement starting from the cold season. The results also suggest that using bred vectors helps to alleviate the tendency of the model to overpredict warm/cold events.

Examination of seasonal predictability using a Perturbed-Parameter Ensemble Method

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The performance of a perturbed-parameter ensemble method (PPEM) for seasonal prediction is examined based on the same statistical method of the multi-model ensemble method (MMEM). We performed 24-yr integrations with prescribed SSTs using the MRI/JMA atmospheric global climate model (MJ98). The 5-member seven ensembles of the PPEM are conducted by varying the six parameters selected. The skill of the PPEM is found to be increased as well as that of the MMEM, and is significantly influenced by the skill of each ensemble.

Overall assessment of ENSO Predictability in 12 CLIPAS and DEMETER Coupled GCM Forecasts

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ENSO predictability of 12 CGCM hindcasts is investigated. The CGCM datasets that come from the CliPAS (Climate Prediction and its Application to Society) and DEMETER (European Multimodel Ensemble system for seasonal to inTERannual prediction) projects are used. The 12 models used are fully coupled ocean-land-atmosphere dynamical seasonal prediction systems with 6 onth integrations for 3 to 15 different initial conditions for four seasons in the common 23 years from 1981 to 2003. As a reference, dynamic-statistical SST forecast skill for tier-two forecast system and persistence of SST is also compared.

Overall description of the state-of-the-art coupled GCM forecasts on ENSO prediction are shown here. Focusing on tropical Pacific region, forecasted annual mean, annual cycle, and its influence on forecast skill is analyzed with respect to lead month. Both multi-model ensemble and each model case are assessed separately. Overview of deterministic and probability assessment of skill is done during 22 years. In addition, current skill of models with respect to ENSO phase and intensity of SST is also depicted in detail. The predictability as the function of ensemble size is estimated and the plausible strategy for multi-model ensemble is suggested based on composite analysis.

The evolution of the subsurface thermal structure in the equatorial Pacific Ocean and its relationship to ENSO

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The interannual variability of subsurface thermal in the equatorial Pacific Ocean is analyzed with particular reference to their relationship with El Nino-Southern Oscillation (ENSO) events. The assimilated data of the Global Ocean Data Assimilation System (GODAS) from the National Centers for Environmental Prediction from 1980-2005 are used in present study. Two of the leading EOFs account for 70% of the monthly thermal variability. The first EOF is characterized by the heat content building up and its eastward and upward propagation. The time series of the principal components (PC1) associated with the first EOF follows the variation of the warm water volume (WWV). The time series of PC1 leads the Nino3 index by two seasons (i.e., six months). The second EOF represents an upwelling in the east coast and a westward propagation near the ocean surface in the equatorial Pacific. These two leading EOFs clearly demonstrate important dynamical roles in the development of a warm ENSO event by both the eastward and upward propagation of the warm mass volume (EOF1) and upwelling and westward propagation of the warm mass volume (EOF2) in the eastern equatorial Pacific. The temperature changes in the sea surface temperature (SST) in these areas provide positive feedback in the El Nino phase, which results from the impacts of the zonal winds changes by means of enhanced deep atmospheric convection patterns. These processes create anomalous winds, which amplify the SST gradient and accelerate the entire process. In the La Nina phase however, an eastward and upward cold mass volume creates a negative feedback, which results from a weakened deep atmospheric convection pattern. An anomalous westward wind slows the eastward propagation of large cold mass volume. This large cold mass volume could rarely reach the east coast of the equatorial Pacific. The upwelling and westward propagation (EOF2) of the cold mass volume is weak, or does not exist in the presence of a large cold mass volume. This negative feedback prohibits the existence of large magnitude La Nina events.

THE IMPACT OF GLOBAL OCEAN/ATMOSPHERE COUPLING ON NH ENSO VARIABILITY : SENSITIVITY TO CONVECTION IN THE TROPICAL NORTHWEST PACIFIC

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We examine the influence of tropical and global ocean/atmosphere coupling on the NH extratropical atmospheric response to the 1997/98 El Niño and 1998/99 La Niña events, using very large ensembles (either 100 or 150 members) of coupled and uncoupled GCM simulations. In all model simulations, observed sea surface temperatures (SST) are prescribed in the tropical eastern Pacific. In the control simulations, climatological SSTs are specified elsewhere, whereas in the coupled simulations a bulk mixed layer model is coupled to the atmosphere in the Indo-Western Pacific ocean or in the entire ocean.

Most of the impact of global air/sea interactions on the ENSO response in our model (GFDL-R30) can be attributed to coupling in the Tropics, which acts to amplify the ENSO teleconnection, with extratropical coupling exerting a weaker counteracting damping effect. The enhancement of the ENSO teleconnection due to tropical coupling is particularly pronounced in early winter of the Niño year, but is absent in midwinter of that same year. Chiefly, this effect is due to an increase, in both the mean and variance, of convection in a small area of the tropical northwest Pacific (TNWP), which occurs via enhanced evaporation associated with a slightly warmer coupled western Pacific. These changes in tropical convection can significantly affect the early winter extratropical Niño response because the PNA region is very sensitive to TNWP forcing at this time, when the Pacific jet is relatively weak and steers the Rossby wavetrain emanating from the TNWP region towards the PNA region. Because this wavetrain interferes constructively with the main ENSO wavetrain emanating from the central equatorial Pacific, the coupled extratropical response to ENSO is amplified. Analogous (but opposite and weaker) results apply throughout the Niña winter. In midwinter of the El Niño year, however, when the Pacific jet is stronger and there is strong mean subsidence in the TNWP region, Rossby waves emanating from this region are trapped in the subtropics and coupling has little impact on TNWP convection or on the ENSO response.

Observational evidence supports the existence of a preferred region in the tropical northwest Pacific for forcing circulation anomalies in the PNA sector in early winter. Thus, how convection in that region is affected by interactions with the ocean may well play an important role in driving ENSO teleconnections.

An Alert Classification System for Monitoring and Assessing the ENSO-Cycle

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An Alert Classification System for the ENSO cycle is introduced. The System includes Watches, Advisories and a five-class intensity scale for warm and cold phases of the ENSO cycle. A Watch is issued when conditions are favorable for the formation of an El Niño or La Niña within the next 6 months. An Advisory is issued when El Niño or La Niña conditions are present, based on NOAA's operational definitions. The intensity scale, referred to as the ENSO Intensity Scale or EIS, is used for operational and retrospective assessments of the intensity of warm (El Niño) and cold (La Niña) episodes, without being prescriptive concerning ENSO-related anomalies or impacts. CPC's monthly Climate Diagnostics Bulletin and ENSO Diagnostic Discussions will serve as the primary vehicles for disseminating real-time information concerning the ENSO Alert Status to the scientific community and public at large.

An objective method that relates the EIS to anomalies is used to assess the effects of warm and cold episodes. The method is illustrated using precipitation in the global Tropics and Subtropics and in the conterminous United States. The methodology is quite general and can be used to relate the ENSO cycle to other quantities.

The climatology and forecast skill of the ECPC Coupled Prediction Model

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We will discuss the new Experimental Climate Prediction Center (ECPC) Coupled Prediction model (ECPM) that is beginning to be routinely used for long lead (up to 12 months) experimental seasonal forecasts. The coupled model consists of the ECPC Global Spectral Model (GSM) coupled to the Jet Propulsion Laboratory (JPL) version of the Massachusetts Institute of Technology (MIT) ocean model used for an ocean analysis each month beginning 1982.

In preparation for these seasonal predictions, a 50+ year long coupled integration run has been performed. The ECPM climatology and the internal variability compares favorably to observations and reanalysis data. Though the model exhibits small climatological biases, these small biases are not larger than the systematic errors produced by other well known coupled models. The internal variability of the model, especially the tropical variability, resembles observations. The model also produces global responses to tropical variability that are quantitatively similar to the observations.

The skill of the ECPM in predicting SST anomalies over the NINO3.4 region is comparable in skill to other coupled model forecasts. The skill of the ECPM seasonal forecasts is also comparable to our current two-tier forecasts and significantly better than persistence forecasts.

Current Status of GFDL's Seasonal / Interannual Prediction System

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The Geophysical Fluid Dynamics Laboratory (GFDL) Seasonal / Interannual (S/I) prediction system is currently involved in a number of collaborations including: 1) The National Oceanic and Atmospheric Administration (NOAA) Climate Test Bed (CTB) program; 2) a project to assist the Asia-Pacific Economic Cooperation Climate Center (APCC) called "Climate Prediction and its Application to Society" or CliPAS; 3) the World Climate Research Programme Coordinated Observation and Prediction of the Earth System (COPES) and 4) participation as a member of the International Research Institute (IRI) real-time seasonal prediction multi-model ensemble system. The GFDL S/I prediction system has near real-time fully coupled (Tier-1) and real-time atmospheric (Tier-2) forecast capabilities. Most forecasts have been run at 2^ox2.5^o lat-lon resolution with 24 hybrid coordinate levels in the vertical. The most recent atmospheric model uses a finite volume (FV) horizontal discretization, with some earlier forecasts employing a B-grid numerical core.

Retrospective ensemble Tier-1 and Tier-2 forecasts have been produced starting from May 1 and November 1 initial conditions. The hindcasts ranged from 5 to 12 months in length through the period 1979 to 2005 with ensemble sizes of 6 to 10 members. Seasonal forecast performance is assessed using a variety of metrics, including anomaly correlations, rms errors and ranked probability skill scores (RPSS). In addition to validation with respect to observations, the GCM predictions are compared with each other for Tier-1 versus Tier-2 and FV atmosphere versus B-grid atmosphere.

The Coupled Wave Oscillator: A New Mechanism for ENSO

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To explain the oscillatory nature of El Nino/Southern Oscillation □(ENSO), many ENSO theories emphasize the free oceanic equatorial waves propagating/reflecting within the Pacific Ocean, or the discharge/recharge of Pacific-□basin-averaged ocean heat content, or the stochastic forcing by intraseasonal variability. ENSO signals in the Indian and Atlantic oceans are often considered as remote response to the Pacific SST anomaly through atmospheric teleconnections. This study validates the above ENSO theories using long-term observational datasets. Space-time spectral analysis is applied to identify and isolate the dominant interannual oceanic and atmospheric wave modes associated with ENSO. Nino3 SST anomaly is utilized as the ENSO index and lag-correlation/regression are used to construct the composite ENSO life cycle. The propagation, structure and feedback mechanisms of the dominant wave modes are studied in detail.

The results show that the dominant oceanic equatorial wave modes associated with ENSO are not free waves, but are two ocean-atmosphere coupled waves including a coupled Kelvin wave and a coupled equatorial Rossby (ER) wave. These waves are not confined only to the Pacific Ocean, but are of planetary scale with zonal wavenumbers 1-2, and propagate all the way around the equator in more than three years, leading to the >3-year period of ENSO. When passing the continents, they become uncoupled atmospheric waves. The coupled Kelvin wave has larger variance than the coupled ER wave, making the total signals dominated by eastward propagation. The two coupled waves interact with each other through boundary reflection and superposition, and they also interact with an off-equatorial Rossby wave in north Pacific along ~15N through boundary reflection and wind stress forcing. ENSO signals in Indian and Atlantic oceans are associated with the two coupled waves as well as the fast atmospheric Kelvin wave, and both ocean processes and surface heat fluxes contribute significantly to the upper ocean heat budget. The discharge/recharge of Pacific-basin-averaged ocean heat content is also associated with the two coupled waves with the Sverdrup transport mainly caused by wind stress curl in the flank of the coupled Kelvin wave. The above results suggest the presence of a "coupled wave oscillator" mechanism for the oscillatory nature of ENSO. Implications for ENSO's statistical predictions, dynamical simulations and predictions, and extratropical teleconnections are discussed.

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An Update on the 2-Teir Seasonal Forecast at ECPC

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In 2002 the Experimental Climate Prediction Center (ECPC) began creating monthly seasonal forecasts using the ECPC Seasonal Forecast Model (SFM). Starting in 2004 the forecasts were run with the updated Noah land surface model instead of the older OSU LSM. In 2005 a downscaled forecast of the western US was added to the forecast, and in 2006 the downscaled forecast was expanded to cover the entire US at a 35 km resolution. This forecast product will soon be merged with a separate weekly to monthly experimental forecast performed at ECPC. A new assessment of the forecast has been made with these changes, which looks at the skill of both the global and downscaled forecasts. The focus of the study is on the differences in skill with older versions of the model as well as the regions and seasons where the model performs well. In addition an initial comparison is made between the global and downscaled forecasts, and the methodology to utilize the ensemble downscaled forecast is pursued.

USE of LINEAR DISCRIMINANT METHODS FOR CALIBRATION OF SEASONAL PROBABILITY FORECASTS

Andrew Colman, Richard Graham, Met Office UK

The linear discriminant method is presented as a tool for calibrating probability bias in seasonal forecasts, such that the probabilities provide an improved estimate of the likelihood of the predicted event occurring. Results of calibration of the Met Office GloSea model and Multi-model (ECMWF, Meteo-France, GloSea) hindcasts produced as part of the DEMETER project will be presented. Results of calibrated GloSea model hindcasts combined with SST based statistical predictions will also be presented.
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When tested using quintile and tercile hindcasts from the GloSea model, replacing raw ensemble probabilities with discriminant calibrated probabilities improves reliability but reduces forecast resolution – as measured by the Relative Operating Characteristic (ROC) diagnostic.. A pragmatic approach that recovers ROC skill whilst retaining the reliability improvements involves generating weighted averages of calibrated and uncalibrated probabilities and results will be presented

Multivariate (MV) discrimanant analysis has also been used to produce calibrated probabilities. The predictors are combinations of GCMs or of GCM and SST based statistical predictions. This method is used in prediction of North and East African rainfall, NE Brazil rainfall and European winter temperature. The MV probabilities are not quite as reliable as single variable discriminant forecasts and can be disproportionate to predictor skill in certain cases. Procedures are being tested to correct these anomalies by for example significance tests on predictors prior to their selection or adapting the discriminant equation to take more account of uncertainty in observations. Examples will be presented and discussed.

An Evaluation of Multivariate Statistical Classifiers
as Seasonal Forecasting Tools

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Simple conditional schemes to predict seasonal climate based on the state of leading ENSO sea-surface temperature (SSTA) and sea-level pressure anomaly (SLPA) indicators provide the means to model and study the effects of forecast information in agriculture, but may be limited in their skill. Here, three multivariate statistical classifiers as evaluated as alternative forecasting methods. These methods are: Discrimination Analysis, a Probabilistic Neural Network that uses a genetic algorithm to select smoothing parameters, and Support Vector Machines. Each provides some added skill in hindcasting winter (November-March) precipitation over a west Texas wheat growing region, relative to simple 3-phase schemes based on equatorial Pacific SSTA and the Southern Oscillation Index. The effect of this improved forecast skill on yield and profit in management simulations is also demonstrated.

Title: **CCA Seasonal Forecast Skill in Multi-Century CGCM2 Simulations**

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The objective of this study is to examine the reliability of the cross-validation as a useful technique in producing true skill in seasonal forecasts. One thousand year climatological simulation of the Canadian Coupled GCM model is used to evaluate seasonal temperature skill over Canada for the four climatological seasons by the Canonical Correlation Analysis methodology. The experimental design involves skill evaluation in 18, 50-year 'out-of-sample' runs, and comparison with the 7, 50-year 'in-sample' runs in which cross-validation is used. Predictors are SSTs which are taken over various domains of the global ocean, and the Northern Hemisphere geopotential heights. Cross-validation is performed with 1, 3 and 5-year out. Temperature skill is evaluated by anomaly correlation, percent correct, and mean square error.

Results show that forecast skill obtained through the cross-validation technique does not reflect the true nature of skill. The 'in-sample' skill is higher then 'out-of-sample' skill consistently. This is true even with 5-year out cross-validation. It is suggested that the forecast models that utilize cross-validation technique overestimate the true nature of skill in seasonal forecasts.

The Met Office forecast for winter 2005/06 over Europe and the UK

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During the summer and autumn of 2005 the Met Office issued and updated a long-range forecast statement warning of a 2 in 3 chance of colder-than-average conditions for the forthcoming European/UK winter. The initial basis of the forecast was the exceptionally large May SST anomalies observed over the North Atlantic, which were configured such as to project strongly negatively on the NAO predictor pattern of Rodwell and Folland (2002) – indicating a marked negative phase NAO for the forthcoming winter season. In subsequent months other predictive inputs were also considered, key among which were guidance from the Met Office coupled ocean-atmosphere global seasonal prediction model (GloSea) and observational monitoring of surface and sub-surface ocean temperatures. The Met Office's decadal forecasting system and output from the European multi-model seasonal forecasting system, EURO-SIP were also used subjectively. The forecast was actively communicated to UK government, business and public sectors – the first time this had been done to such an extent for a seasonal forecast.

In the event Europe did experience a colder-than-average winter, with anomalies of between -1 and -3ºC observed over wide areas. The prediction methods used in the forecast and their long-term track record will be reviewed, and guidance for winter 2005/6 compared against the observed conditions. Lessons learnt from both the production and communication of the forecast will be discussed and plans for a research focus on improving prediction skill over the European region outlined.

Statistical Climate Prediction for the Interior Southwestern U.S.: Assessment of Forecast Skill From Seven Years of Experimental Seasonal Forecasts

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New and improved "climate divisions" can be used for the statistical prediction of climate anomalies (here: precipitation) in the interior southwestern U.S. Experimental precipitation forecasts were first issued in late 2001, and are updated monthly on the internet (http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/). Since the original data training period ended in September 1999, there will be seven years of verification data available by October 2006.

Seasonal forecast skill for the interior southwestern U.S. appears to be linked not only to ENSO (and its various 'flavors'), but also to SST regions further afield (Indian Ocean) as well as closer to the U.S. (eastern subtropical Pacific and Caribbean). Other useful predictors include northern hemispheric teleconnection patterns, and antecedent regional precipitation anomalies. Verification skill for the last seven years exhibits large regional and seasonal variations, but has remained positive for all seasons, in contrast with official Climate Prediction Center forecasts for much of the region. The poster highlights the regions and seasons with the highest skill, and reports on possible contributors to this skill.

Verification and Validation of the Australian Bureau of Meteorology's Seasonal Climate Outlook model; what the results may suggest for future Australian outlooks

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The Australian Bureau of Meteorology routinely (monthly) issues an objective seasonal climate outlook for rainfall, maximum temperature and minimum temperature, based upon a linear discriminant analysis of their relationship with Pacific Ocean and Indian Ocean Sea surface Temperature (SST) values. These outlooks cover the entire country, and are issued via the web as forecasts of the probability of achieving above median outcomes, or via a booklet which shows tercile probabilities. Further experimental outlooks have looked at different forecast parameters, such as the probability of exceedance of certain rainfall thresholds. Validation (i.e., assessment of cross validated hindcasts) has been performed on the model for the 50 years, 1950 to 1999. Multiple assessment methods have been used, with the general suggestion of reasonable forecast skill, particularly during the southern winter and spring, for rainfall. The validation of temperature outlooks suggests even higher levels of skill. Verification (assessment of independent forecasts) has also been performed on forecasts from 2000 to 2006. For both rainfall and temperature, there is a considerable difference between the regions of skill suggested by the validation and verification. For minimum temperatures, areas of Western Australia are shown to have shifted from considerable implied skill to low skill, for maximum temperatures there appears to be considerably more skill in general, and for rainfall there is only a loose resemblance between the verification and validation results. While it is recognized that the verification period is a small sample compared to the validation, the impact of generally warmer SST values are a possible cause of apparent changes in forecast skill with this model.

Oceanic Skill Sources for U.S. Seasonal Climate: Old versus New AGCMs

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This study is an extension of our previous analysis on the sources of U.S. seasonal climate simulation and prediction skills. Here, a suite of 50-member multi-model ensemble simulations by 4 new atmospheric general circulation models (AGCM) is included in addition to the 47-member ensemble simulations by 4 "old" AGCMs.

The new AGCM's skill for U.S. seasonal temperature and precipitation is improved compared to the old models. Modest improvement occurs mainly in the seasons of fall to early winter for U.S. precipitation and from summer to early winter for the surface temperature.

Results of the skill source analysis for the new models are consistent with those obtained based upon the old models: (1) most of the AGCM's skill is attributed to a leading source of ENSO; (2) The air-sea interaction in the western Pacific Ocean serves as another skill source that is especially important for the skill of U.S. temperature during the seasons from late-summer to early winter.

A Comparison of Atmospheric Variability in Tier-1 vs. Tier-2 NCEP Climate Forecast System

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Abstract

In order to quantify the influence of model biases in coupled ocean-atmosphere evolution on the atmospheric variability, we compare seasonal climate variability between coupled and uncoupled with SST bias correction forecasts of the NCEP Climate Forecast System. It is important to investigate how well seasonal atmospheric variability is represented in the uncoupled simulations when sea surface temperatures are specified. Ensemble means of 200hPa geopotential height (Z200), precipitation, and SST between coupled (tier-1) and uncoupled (tier-2) retrospective forecast (1981 – 2004) are analyzed to quantify possible differences in atmospheric variability. Tier-1 and Tier-2 predictions are compared to the observations to determine the accuracy of atmospheric variability.

Resolution dependence of global model in SMIP simulations

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Recently, a new global model is developed by the Yonsei University under the project for the development of a new KMA global forecast system embarked by KMA in 2002, which is named YOnsei University Research model System (YOURS). The starting point of the new model system is routed in the NCEP global forecast system (GFS) as of 2000 (Kanamitsu et al. 2002a), but with major differences in dynamics and physics. New global model employs a Double Fourier Series (DFS) dynamic core (Cheong 2000, 2006; Cheong et al. 2004). Also, the YOURS global model adopts new physical processes optionally including radiation, boundary layer processes, and so on (Hong and Park 2005).

This study examines the dependence on the horizontal resolution in SMIP simulation under the original model (NCEP GFS) framework. The purpose of this work is to prepare references for investigating the characteristics of newly developed global model and for assessing its performance in long-term climate simulation. Three experiments with low (T62) and high resolutions (T126, T248) are designed to investigate the resolution dependence of the model on the simulated climate. The simulation period is 10-year boreal summers from 1995 to 2004. For each experiment, 10-member ensemble runs are performed, starting from 0000 UTC of 1 May to 1200 UTC 5 May with 12-hr interval for each year. And observed sea surface temperature, sea-ice and snow data are prescribed during the simulation period. More detailed results will be discussed later.

Dependence of internal variability on SST forcing in a large ensemble size GCM simulations

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The internal variability in the first and second moments of probability density function (PDF) of December-January-February (DJF) seasonal means during 1950-2002 are analyzed using an 85 members ensemble simulation forced with the observed SSTs. The strength of Nino-3.4 SSTs index for the period of 1950-2002 are categorized into five separate bins from strong cold to strong warm ENSO events.

The main focus of the analysis is to study the influence of observed SSTs on changes in seasonal mean and the internal variability of extratropical 200-mb circulation pattern and tropical rainfall using a large ensemble size. The results indicate that internal variability of the tropical rainfall anomaly over equatorial tropical Pacific decreases (increases) for the cold (warm) ENSO events. The seasonal mean variability for upper level circulation decreases for the warm events and increases for the cold events. Further, the analysis confirms that the influence of the interannual SST variability is much stronger on the first moment of seasonal means compared to their influence on the second moment. The results imply that the seasonal predictability due to changes in SSTs can be attributed primarily to the shift in the PDFs of the seasonal means and less to changes in their spread.

The dominant modes of internal variability of extratropical 200-mb heights for different SST categories are also analyzed. The results suggest that the dominant mode of internal variability has a small dependence on tropical SST forcing. On the other hand, the tropical SST forcing has larger influence on the second mode of internal variability. The spatial location of the second mode moves eastward for cold to warm events. The spatial patterns for the cold events are very much similar to Pacific-North American (PNA) pattern and warm events resembles to tropical-North Hemisphere (TNH) pattern.

Optimal Multi-Model Ensemble Technique in the CliPAS and DEMETER Seasonal Climate Prediction

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Multi-model ensemble technique is a popular tool to increase a predictive skill of the state-of-the-art prediction models. Because the multi-model ensemble reduces systematic biases of single models due to incomplete dynamical and physical processes, better model performance can be obtained. To maximize the reduction of systematic bias, various multi-model ensemble techniques have been developed and applied to not only weather prediction but also seasonal prediction. In this study, multi-model ensemble techniques are applied to the seasonal climate prediction using DEMTER and CliPAS experimental seasonal prediction data.

Three multi-model ensemble techniques are applied and compared. One is MME1, which is a simple composite method. In this case, the ensemble mean is obtained by averaging different predictions with even weighting coefficients. Another is MME2, which is a weighted ensemble method. This averages the predictions with different weighed coefficients. The weighted coefficient is obtained by the SVD method to minimize root-mean-square error in the cross validation method. The other is MME3, which is a corrected ensemble method. After the prediction is statistically corrected, the corrected predictions are averaged with even weighting coefficients. For the statistical correction, a Stepwise Pattern Projection Method (SPPM) is newly developed.

Using the DEMETER and CliPAS data, a total of 15 seasonal predictions models and 21-yrs prediction sample are applied to the three multi-model ensemble techniques. In this case, because the number of prediction models is large but the number of sample years is small, the statistical over-fitting can result in serious degradation of the forecast skill in the statistical management. When the predictive skills between three multi-model ensemble techniques are compared, the MME2 shows distinguishable degradation of the forecast skill due to the over-fitting problem. In particular, the degradation of the forecast becomes more serious as the number of models increases. On the other hand, the MME3 has comparable skill compared to that of the MME1. Over the ENSO region where each single model has already high predictive skill, it seems the MME1 is superior to the MME3 because the statistical correction is not effective in this region. However, over outside of the ENSO region, the MME3 has better skill than the MME1. In particular, the MME3 works very effectively over the western Pacific and subtropics where the systematic biases of the single models are large. Based on these results, finally, optimal multi-model ensemble technique is suggested in this study.

Predictability of the thickness and extent of Arctic sea ice with linear models and coupled ice-ocean model simulations.

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The predictability of the total and regional ice extent and thickness of Arctic sea ice is investigated for periods of one month to one year. The output of a coupled ice-ocean model, forced with observed atmospheric conditions and incorporating assimilation of ice concentration and velocity, is used to determine the best linear model for predicting ice conditions up to one year in advance. We first concentrate on predicting the Arctic-wide minimum ice conditions in September and find that different sets of model estimates of the ice thickness, the ocean temperature at various levels, or the ocean velocity are optimal for different prediction intervals. Mean ice thickness is more predictable than ice extent. We then investigate the predictability of ice conditions in different sectors of the Arctic and in different seasons. The secular trend in the ice conditions contributes a substantial portion of the variance explained by the predictions and the predictability of the detrended ice conditions is much less than for the original observations. The estimates of the ice thickness and ocean temperatures from the model offer significant advantages for predicting ice conditions over schemes based on satellite observations of ice extent alone.

Predictability on intraseasonal oscillation activity in climate prediction models

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The summer intraseasonal variability and its predictability are examined by using ten state-of-the-art seasonal prediction models. The analysis is based on the APCC and DEMETER hindcast output from 1981 to 2001. This study distinguishes itself from the previous intercomparison works in that it uses the real historical prediction data from models. The spatial patterns of summer mean state and ISO in climatological view are reasonably well captured by the model composite. Moreover, although the individual prediction model shows variety in simulating the climatological patterns, the relationship between summer mean and ISO are highly correlated as in observation. In other words, models which simulate the pattern of mean state reasonably well can also represent the ISO activity well, and vice versa. Likewise, results also demonstrate that model with high (low) predictability of mean state is associated with high (low) predictability of ISO activity. The dominant interannual mode of ISO activity is linked to ENSO and models have an ability to capture this prominent mode. It is shown that ENSO-induced wind shear in the western and central tropical Pacific is crucial for the ENSO-related changes of ISO activity both in observation and models. Because of the close relationship to the external SST forcing, a statistical correction method is applied and corrects a large part of the systematic errors of ISO activity. After statistical correction, the predictability is enhanced in most of the prediction models.

A new cloudiness parameterization based on cloud water for seasonal numerical forecasts.

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Clouds are one of the most uncertain components in climate models and model results are known to be very sensitive to the cloud parameterization. The accurate simulation of cloudiness is particularly important for ocean atmosphere coupling. In this study, relationships between relative humidity, cloud water and cloud amount are examined using observation, reanalysis and model simulations. The International Satellite Cloud Climatology Project (ISCCP) D2 series data (Rossow and Schiffer, 1999) was used for cloud amount and cloud water path, and NCEP/DOE reanalysis 2 data (R-2; Kanamitsu et al., 2002) was used for relative humidity. Scatter diagrams of relative humidity and cloud amount, and cloud water and cloud amount show that the correlation between cloud water and cloud amount is high while there is no systematic relations between relative humidity and cloud amount. This suggests that there is a possible advantage in predicting cloud amount from cloud water alone compared to predicting from relative humidity and cloud water.

Using 6-hourly observation, ISCCP D1 series data (Rossow and Schiffer, 1999) and reanalysis, a new formula to calculate cloudiness from cloud water without the use of relative humidity is proposed:

$$\text{cloud amount} = a*[1-\exp(-b \square m)] \qquad (1)$$

where m is cloud water content, a and b are constant derived from observed 6 hourly cloud amount and cloud water. It is similar with Randall (1995)'s formula, but its dependency to relative humidity is removed. Using Global version of the Experimental Climate Prediction Center's (ECPC) Global to Regional forecast system (hereafter ECPC-GSM), the impact of new formula in seasonal forecast has been examined. As a control run, cloud amount is calculated from relative humidity based on Slingo and Slingo (1991). In this study, Hong's cloud water scheme (Hong et al., 2004; hereafter CLD3) is used to evaluate the new formula. CLD3 has cloud water/ice and rain/snow water as predictive variables and now it is a part of WRF model. The impact of new formula on seasonal forecast shows that this approach is promising. But new formula tends to suffer from model bias, which appears in simulated cloud water. In addition, the setting of minimum value of cloud water to calculate cloud amount seems to be needed to prevent the cloud water distribution from spreading too much due to Gibbs phenomena. Further refinement of the scheme is in progress and the application of the method to seasonal forecast will be presented.

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Importance of a Viable Stratosphere for Climate Forecasts

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The importance of the stratosphere in a forecast model is generally overlooked. However, as the forecast time increases from hours to days to weeks, the role of the stratosphere increases dramatically as the stratosphere interacts with the troposphere radiatively and dynamically. We will summarize recent work, showing the importance of the stratosphere in the forecast model for enhancing climate forecasts, in terms of skill in the troposphere and stratosphere. Examples will be given of how improvements in the depiction of the stratosphere in NCEP models contribute to enhanced forecast skill. For instance, use of enhanced quality ozone information in the GFS is shown to improve the radiation balance in the stratosphere and troposphere, thus contributing to the skill in extended range forecasts. Also, improvements in forecasts of ozone and an improved longwave radiation package combine to improved skill in the troposphere in longer climate forecasts.

On Forecasting Pacific SSTs: Using a Linear Inverse Model to Predict the PDO

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Given that accurate dynamical predictions of the North Pacific oceans is extremely difficult due to the complex nature of the extratropical atmosphere-ocean system, we have developed a statistical model to predict pan Pacific sea surface temperature (SST) anomalies. It is critical to include the tropical Pacific to predict variability in the North Pacific, including the Pacific Decadal Oscillation (PDO), as ENSO teleconnections have a significant impact on the extratropical oceans. The statistical method, termed linear inverse modeling (LIM), based on an assumption of stochastically forced linear dynamics. Currently the input and forecasts from the model are seasonal SST anomalies over the Pacific basin north of 30°S. Preliminary results indicate that the model has skill over much of the Pacific for 2-3 seasons in advance and up to a year in some locations (Fig. 1). The correlation between the predicted and observed PDO for all seasons during 1971-2001 is 0.81, 0.64, 0.55 and 0.44 at leads of 1, 2, 3, 4 seasons, respectively. These values are significant at the 95% level and are comparable to LIM-based forecasts of SSTs in the Nino 3 region and generally better than general circulation models.